"SOME PHYSICOCHEMICAL AND BACTERIOLOGICAL STUDIES ON EXTENT AND SEASONAL TRENDS IN POLLUTION AND POTABILITY OF GROUNDWATER IN KANPUR METROPOLIS"

A

THESIS

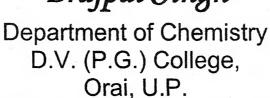
Submitted to BUNDELKHAND UNIVERSITY, JHANSI U.P.

For the Award of The Degree of

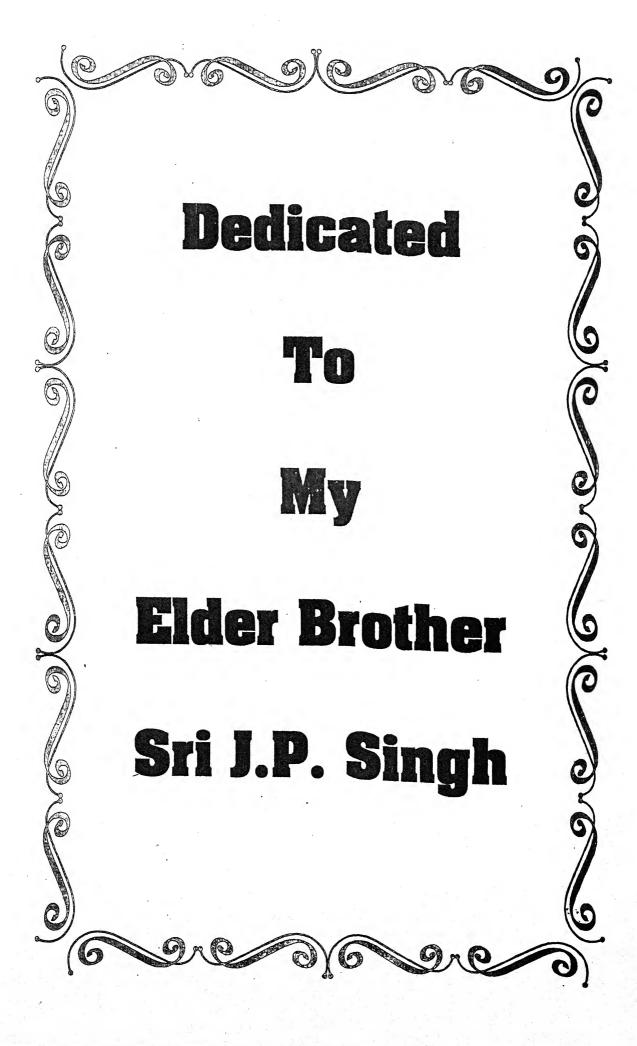
DOCTOR OF PHILOSOPHY

IN **CHEMISTRY**

by Brajpal Singh



2003



DECLARATION

I hereby declare that with the exception of the guidance and suggestions received from my supervisor, Dr. S.C. Khurana, Reader, Deptt. of Chemistry, Dayanand Vedic College, Orai, U.P., this thesis is my own unaided work carried out in the Post Graduate Deptt. of Chemistry, D.V.(P.G.) College, Orai, and Fertilizer and Pesticide Quality Control Lab, Meerut, U.P.

I further declare that this is an original piece of my research work and has not been submitted anywhere else to the best of knowledge.

December, 2003

Brail pal Singh.

Brajpal Singh
Department of Chemistry
D.V. (P.G.) College,
Orai, U.P.

Dr. S.C. Khurana

Ph.D.

Deptt. of Chemistry
Dayanand Vedic Post Graduate College,
Orai, (U.P.)

E-mail: ess cee kay2002@yahoo.co.in

2 - 05162-250333 (Res.) 05162-252214 (Off.)

CERTIFICATE

This is to be certified that the thesis entitled "Physicochemical and Bacteriological Studies on Extent and Seasonal Trends in Pollution and potability of groundwater in Kanpur Metropolis" submitted by Brajpal Singh embodies the work of the candidate himself. He worked hard in the laboratory of Chemistry Department of the Institution under my guidance. The thesis is suitable for the submission for award of the degree of "Doctor of Philosophy" in Chemistry of Bundelkhand University, Jhansi. Such work has not been submitted to any other University.

December, 2003

(Dr.S.C. Khurana)

Letander &

ACKNOWLEDGEMENT

It gives me immense pleasure and honour in expressing my deep gratitude and privilege to a person of extra ordinary calibre, versatile, genius, humble, philosopher and guide. I am indeed beholden to **Dr. S.C. Khurana**, **Reader** and Coordinator of Industrial Chemistry, D.V. (P.G.) College, Orai for his ready acceptance to direct the present investigations. It was a gracious gesture on his part to share his valuable time inspite of his busy schedule. His gentile demeanour and loving behaviour, helped me cross several obstacles with comparative ease. No words can adequately express my heartfelt gratitude and fathomless indebtedness to my kind hearted, esteemed guide.

My sincere thanks to **Dr. N.D. Samadhiya**, Present Principal **Dr. G.S. Niranjan**, Ex-Principal D.V.(P.G.) College, Orai and Prof. I.M. Beg Head of Department of Chemistry for providing necessary facilities for successfully carryout my research.

My heart is filled with a deep sence of thankfulness and obeisance to Dr. H.S. Yadav, Dr. Ram Lakhan, Er. S.K. Jain, U.P. Jal Nigam and Sri S.C. Nagar, Scientist F.P.Q.L., Meerut, Dr. S.K. Mishra, Principal, D.B.S.(P.G.) College, Kanpur, Dr. Rameshwar Prasad Dwivedi, Ex-Principal, R.S.G.U. (P.G.) College, Pukhrayan, Kanpur Dehat, Dr. Ashok Kumar, Principal P.V.M. Baraur, Kanpur (Dehat).

I wish to put on record my gratitude to motherly Smt. Asha Khurana, and family members. I am thankful to The Director, Central Pollution Control Board, Sharda Nagar, Kanpur for providing literature on pollution and suggestions and Director, Fertilizer and Pesticid Q ty Control Lab, Meerut for the permission of use of photospectron r, N.M.R., Chromatograph etc.

Special thanks are due to my parents, Bhabhi Smt. Sonlata Yaw whose blessings and encouragement were always available to conme during difficulties.

I also acknowledge sincere co-operation and affection of ny friends, Rajneesh Khare, Pravesh Ranjan Goel, Awaneesh, Vivek Pandey, Satyam, Jagmohan & my colleagues. They inspired me always in to strive for excellence and help me tackle this task with pleasure and ease.

At last but not least, I offer my thanks to my well wishers whose names could not be acknowledged individually.

Place: Orai

Date:

(BRAJPAL SINGH)

<u>CONTENTS</u>

		PARTICULARS	PAGE NO.
Chapter - I	Prelude and Review		1-30
	1.1	Introduction	1
	1.2	Environmental Pollution	2-3
	1.3	Groundwater and its availability	4-7
	1.4	Pollution of Groundwater	8
	1.4.1	Chemical Factors Influencing by Groundwater Pollution	9
	1.4.2	Groundwater Pollution in action	9
	1.5	Groundwater availability in India	11
	1.5.1	Pre - Cambrian Gystalline province	11
	1.5.2	Pre - Cambrian Sedimentary Province	13
	1.5.3	Gondwana Sedimentary Province	13
	1.5.4	Deccan Trap Province	13
	1.5.5	Cenozic Sedimentary Province	14
	1.5.6	Genozoic Fault Basin	14
	1.5.7	Ganga, Brahmaputra Alluvial Province	14
	1.5.8	Himalayan Highland Province	15
	1.6	Factors Responsible for Groundwater Pollution	16
	1.7	Health Hazards due to Polluted Groundwater	17-18
	1.8	Brief Review of Present status of pollution	19
	1.8.1	Groundwater Pollution in Indian Urban areas.	21-23
	1.8.2	Case studies of groundwater pollution in Indian cities	24-28
• .	1.8.3	Potability of Groundwater	29
	1.8.4	Protection of Groundwater Resources	29
	1.9	Area and Scope of present Investigation and analysis under taken	30-33
		References	34-53

Chapter - I I	Material, Methods and Procedure		55-89
	2.1	Introduction	55-60
	2.2.1	Physicochemical Examinations	61-80
	2.2.2	Analytical Methods	81
	2.3	Estimation of Heavy Metals	81-82
	2.3.1	Preliminary Digestion of Metals	83-85
	2.3.2	Procedures for Determination of Heavy	86-87
		Metals	
	2.4	Bacteriological Examination of Water	86
	2.4.1	Preliminary Test	87
	2.4.2	Confirmation Test	88
	2.4.3	Completed Test	89
	2.4.4	MPN Method for Faecal Coliforms	89
		References	91-93
Chapter - III	Variation and Trends in Quality of Groundwater in Kanpur Metro		94-150
	3.0	Introduction	94
•	3,.1	Results and Discussions	95-100
	3.1.01	pH Standard Range 6.5 to 8.5	101
	3.1.02	Alkalinity .	102
	3.1.03	Electrical Conductivity	103
	3.1.04	Total Dissolved Solid	104
	3.1.05	Total Hardness	105-07
	3.1.06	Sulphate	108
	3.1.07	Chloride	109
	3.1.08	Fluoride	110-111
	3.1.09	Nitrate	112
	3.1.10	Iron	113
	3.1.11	Copper	114
	3.1.12	Cadmium	115
	3.1.13	Chromium	116
	3.1.14	Zinc	117
	3.1.15	Lead	118

	3.1.16	Manganese		119
	3.1.17	Nickel		120
	3.1.18	Coliforms		120
	3.2	Trends and Discussion		121
	3.2.1	Seasonal Trends		122-149
	3.2.2	Sub Area wise Trends and Discussion		150
		References		185-189
Chapter - IV	General Discussions, Suggestions, and 19 Recommendations			190-217
	4.1	Introduction		190
	4.2	Groundwater Storage		191-192
	4.2.1	Groundwater Reservoir Systems		193-195
	4.3	Artificial Recharge		196
	4.3.1	Objectives and Basic Principle		196-197
	4.3.2	Methods of Artificial Recharging		198-200
	4.3.3	Quality of Water for Recharging		201-202
	4.3.4	Environmental Problems of Artificial		203-206
		Recharging		
	4.4.1	Pollution Control at Sources/ Source Reduction		207
	4.4.2	Resource Recovery		208
	4.4.3	Sewerage Regulation		209
	4.4.4	Role of Private Sector Companies		209
	4.5	Management of Groundwater Resources		210
	4.5.1	Demands for Waters		211
	4.5.2	Availability of Water		212
	4.5.3	External Constraints		212
	4.5.4	Technology of Water Management		213
	4.6	Water Conservation		214
	4.6.1	Agriculture		215
	4.6.2	Industries		216
	4.6.3	Domestic use		216
	4.7	Conclusion		217-219
		References		220

′

LIST OF USED ABBREVIATIONS

•	SHM	Standard Hard Water
•	Phe	Phenolphthalein
•	MeO	Methyl Orange
• ,	EDTA	Ethylene Di Amine Tetra Acetate
•	EBT	Erichrome Black-T
•	рН	Presence of - log H ⁺ Ion concentration
•	PH	Permanent Hardness
•	SPANDS	(2-Parasulphophenylazo)-1,8, dihydroxy-3, 6,
		Naphthalene Di Sulphate
•	HIG	Higher Income Group
•	MIG	Minimum Income Group
•	LIG	Lower Income Group
•	JJ	Juggi Jhopari
•	IA	Industrial Area
•	EC	Electrical Conductivity
•	HCL	Hollow Cathode Lamp
• *	MIBK	Methyl Iso Butyl Ketone
•	MFW	Metal Free Water
•	APDC	Ammonium Pyrrolidine Dithio Carbamate
•	НМ	Heavy Metal

MPN Most Probable Number

BGLB Brilliant Green Lactone Bile

E.Coli
 Escherichia Coliform

TDS Total Dissolved Solid

AGS American Geologic Survey

• T.Alk. Total Alkalinity

T.H. Total Hardness

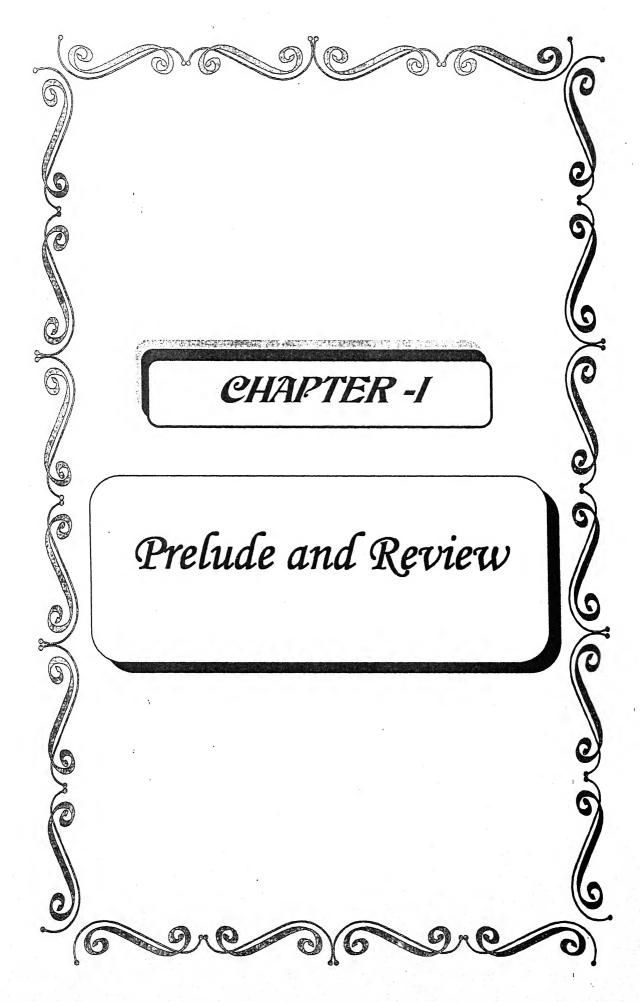
• = Equal To

• = Equivalent To

• ≈ Approximately Equal To

• mg Milligram

• μmg Micro Milligram



PRELUDE AND REVIEW

1.1 INTRODUCTION

Ground Water pollution is man made problem which needs urgent attention of those concerned with pollution, pollution control and the consumer. However, before we go into the realm of the specific problem of ground water in a city like Kanpur Metro, it would be worthwhile to have a holistic picture of environmental pollution to get the right perspective.

The world 'Environment' is etymologically derived from an old French world 'environ' meaning 'encircle. We, the human kind on earth, are encircled right from the time of our birth. We are surrounded by plants, air, physical objects, animals, people etc. which give us physical substance and affords us the opportunity for moral, intellectual social and spiritual growth.

We may, therefore, broadly define environment as the outer physical, biological and social systems in which we live. In brief, it is a sum total of all conditions and influences that affect the development and life of organisms.

Environment consists of abiotic, biotic and energy components¹. The abiotic component involves lithosphere (the earth's crust including soil), atmosphere (blanket of gases surrounding the earth) and hydrosphere (all types of water

sources). The biotic component consists of the realms of living organisms and their interaction with environment. The energy component includes solar energy, geochemical energy, hydroelectrical energy, nuclear energy, etc. All living species of plants and animals inference their environment and in turn get influenced by it.

The extent of such natural impact is not high in these species. However, man interacts exceptionally with nature and can modify the environment in a variety of ways according to his requirements, knowledge, and values. Ever increasing urbanization, surging population, ever expanding industries, the green revolution and their aftermath have together resulted in a problem termed as environmental pollution which possibly occupies the first place in the world even before the problem of unemployment and inflation.

1.2 Environmental Pollution

Environmental pollution is an unfavourable alteration of the environment from the effects of changes in the energy pattern (such as heating of waterways), radiation levels such as radioisotopes and fallout from nuclear weapon tests, chemical and physical constitution of the atmosphere by sulphur dioxide and other pollutants or abundance of organisms such as bacterial infection agents. The factors deteriorating the quality of environment are known as pollutants. Generally, a pollutant is a harmful solid, liquid or gas present in such concentration in the environment

which tends to be injurious to all biological and sometimes even the physical species. Pollutants are of several types and can be classified in different ways on the basis of their nature, i.e. natural or man made: local or continental; biodegradable or non-biodegradable; solid, liquid, gaseous or energy forms, etc. Similar to pollutants, pollution may be classified as air pollution, thermal pollution, agricultural pollution, solid waste pollution, water pollution, etc. which may be natural or man made, local, national, international or even planetary engulfing the entire biosphere.

After Oxygen which forms the vital part of environmental atmosphere, fresh water is the most important substance for sustaining human life. Like earth, fire and air, it was revered by the ancients and was treated by all with respect. Throughout the intervening millennia, human settlements, human activities and human festivities have celebrated the goodness of fresh water. Today, however, we no longer honour water with same dignity. Human indifference, ignorance and greed combine globally, to waste it, foul it and divert it, thereby denying it to neighbours and fellow creatures. Now a crisis looms and as we run short of water; we also run out of time.

Availability of water for hygiene, health, sanitation, agriculture and industry is today considered a basic human right. But there is simply not enough water to go round, from the slums of Mexico to the outburdened farms of China, from the irrigated desert of South-west America to the dead shores of once vibrant

Aral Sea. Not only are we outstripping the planets' limited fresh water stocks, but we are rapidly poisoning the fluid that sustains life.

A mere 1 per cent of all water on the planet is readily accessible for use. Of this amount 73 per cent goes to agriculture, another 20 per cent goes to industry and the remaining 7 per cent is used for drinking, domestic and recreational needs. These figures, however, do not reveal the great variations from region to region. In Eastern Europe 80 per cent fresh water is consumed in industry while in Ghana industry accounts for only 3 per cent. Most citizens in developed nations like Canada can have a shower every day and drink their fill of tap water, but for untold millions, the shortage of clean water means epidemic, hunger, despair and death. According to the United nations 40,000 children die every day, many of them are the victims of diarrhoea and other side effects of water crisis.

1.3 Groundwater and its availability

What is ground water? It is the underground water that has come mainly from the seepage of surface water and is held in the subsoil and pervious rocks. It is the part of the groundwater cycle (Fig. 1.1). The cycle beings with the water evaporating from the water bodies forming clouds which on cooling release water as rainfall. A very small amount of rainwater percolates into the soil to become subsurface, which is taken by the plants. A portion is evaporated directly, and some resists evaporation and is held by

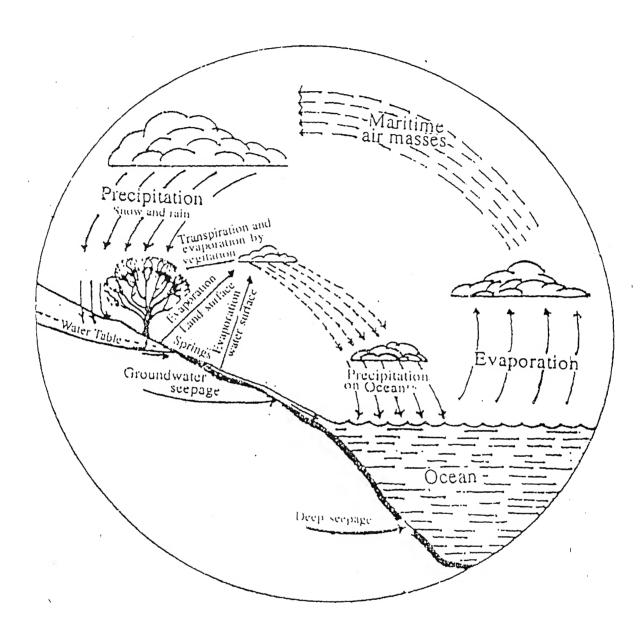


Fig.1.1 Groundwater Cycle

the soil. The balance of the percolating water passes downward under the influence of gravity until it reaches an impervious stratum or aquiclude. It then begins to move in a lateral direction towards same outlet called zone of saturation and its water is called groundwater.

It is known that chemical quality of groundwater is dependent upon the depth zone in which it is found as studied by Saha and Sarkar¹. Indeed water occurs in distinctly different zones ³⁻⁵, below the surface of earth as shown in fig. 1.2. The uppermost or unsaturated zone extends from the land surface to depths ranging from very shallow in humid area to much deep in arid regions. The cavities in this zone contain both water and air; so it is called unsaturated zone. Below this is the saturated zone containing only water. The water table is the upper part of this zone where water occurs at atmospheric pressure. A capillary fringe, which is maintained by the strong surface tension of water, occurs in this zone. The water below the water table is known as groundwater.

Groundwater is precious and most widely distributed mineral resource of the earth and is annually replenished from the rainwater precipitation. The world's total water resources are estimated at 1.37x108 millions hectare metres. Of the entire global water resources about 99 per cent (1.356x108 million hectare metres) cannot be consumed because it is either saline (97% in oceans and sea) or locked up as solid in polar ice caps, glaciers and

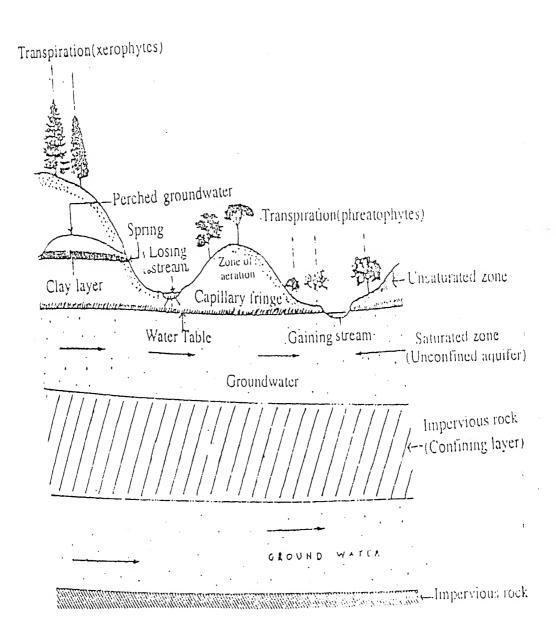


Fig. 1.2 Occurrence of Groundwater

ice sheets (2%). Most of the remaining water (1%) is fresh and worth using and is present in rocks as groundwater (0.99% i.e. about 1.356×10^6 million hectare metres) and about 0.01 per cent (1.37 x 10^4 million hectare metres) of water on the earth is present in surface reservoirs like rivers, lakes, ponds, springs, etc. Out of the total stored groundwater, only about 0.3% (40.68x 10^4 million hectare metres) can be economically extracted with the present drilling technology and the remaining is unavailable situated below a depth of 800 metres.

1.4 Pollution of Groundwater

Groundwater is stored mainly in aquifers that are geological formations of saturated zones of rocks, sand or gravel. Aquifers are recharged as atmospheric precipitation seeps into ground or as surface water drains into them. Aquifer recharge rate depends upon a number of factors including the depth of groundwater below the surface as well as the depth and type of sources above the aquifer. In many regions recharge areas are near the surface and may be affected by agricultural residential and industrial activities. Once groundwater is contaminated, it becomes difficult or sometimes impossible to restore it to its initial quality. Groundwater is, not directly accessible, once it becomes contaminated, there are major difficulties both in monitoring and cleaning it⁶.

1.4.1 Chemical factors influencing by groundwater pollution

Dissolved constituents in groundwater are generally only a small fraction of total weight of the water. The *pH* of groundwater (usually 5-8) changes due to contamination. Water as rain or snow contains only a small quantity of dissolved minerals. However, it reacts with minerals of soil and rocks of the earth crust. The amount of mineral matter dissolved by water depends upon the chemical composition and physical structure of the rocks, temperature, pressure, duration of contact, material already in solution, *pH* and redox potential. Water is assisted as a solvent by CO₂ from atmosphere or by organic processes.

Most of chloride in groundwater comes from entrapped sea water, solution of minerals and evaporation of precipitation. Most of nitrate in groundwater is derived from organic sources or agricultural chemicals⁷⁻⁸. Dissolved gases occurring in groundwater include O₂,CO₂, H₂S, CH₄, NO, SO₂, and NH₃. These are commonly derived from atmosphere and from decaying organic matter. In general, the solubility of a gas in water varies inversely with temperature and directly with pressure⁹.

1.4.2 Groundwater Pollution in action

Industrial and municipal effluents, landfills, septic tanks, mining and agricultural practices can potentially contaminate groundwater with toxic chemicals. Contamination also depends on geology and hydrology of the area¹⁰⁻¹¹.

Chemicals pass through different hydrological zones as they migrate through the soil to the groundwater systems. The pores in the unsaturated zone are occupied by both air and water. So flow in this zone for liquid contamination is downward by gravity. In the upper region of the unsaturated zone, some chemicals are retained by adsorption into organic matter and chemically active soil particles. These adsorbed chemicals get decomposed through oxidation and microbial activity. Below the soil zone, the pore spaces are also unsaturated and as chemicals pass downward, oxidation and aerobic biological degradation occur. In the capillary zone, spaces between soil particles may be saturated by water rising from water table. Lighter chemicals float on the top of the water table in this zone and move in different directions and rates with dissolved contaminants. Once dissolved contaminants reach the water table, they may flow in both depending on hydraulic horizontal and vertical directions gradients. All the pore spaces between soil particles below the water table are saturated and lack dissolved oxygen and limit the oxidation of chemicals and groundwater flow is laminar with minimal mixing occuring as the groundwater moves. Since groundwater involves laminar flow, dissolved chemicals follow groundwater and form distinct plumes. These plumes of contaminated groundwater may be upto several miles downstream

of the pollution source. Generally average rate of plume movement is less than 30 cm a day.

1.5 Groundwater availability in India

About two -thirds of the total land area in India consist of consolidated formations, 75 per cent of this is made up of crystalline rocks and consolidated sediments, the remaining 25 per cent being trapped. The rest of one-third of the total land area comprises of semi-consolidated and unconsolidated formations like alluvial tracts. The potential areas of groundwater in India are shown in Fig. 1.3. Taylor classified following groundwater provinces in India-

1.5.1 Pre-Cambrian Crystalline Province

This zone covers nearly 50 per cent of the area of the Indian subcontinent, extending discontinuously from Delhi to Kanya Kumari underlain by igneous and metamorphic rocks chiefly of granite, gneiss, quartzite, schist, phyllite and marble. Groundwater occurs mainly within the depth of less than 50 m occasionally down to 100 m and rarely below this depth. Total dissolved solid (TDS) values rarely exceed 200 ppm and hardness is low, high concentrations of fluoride has been reported in many areas.

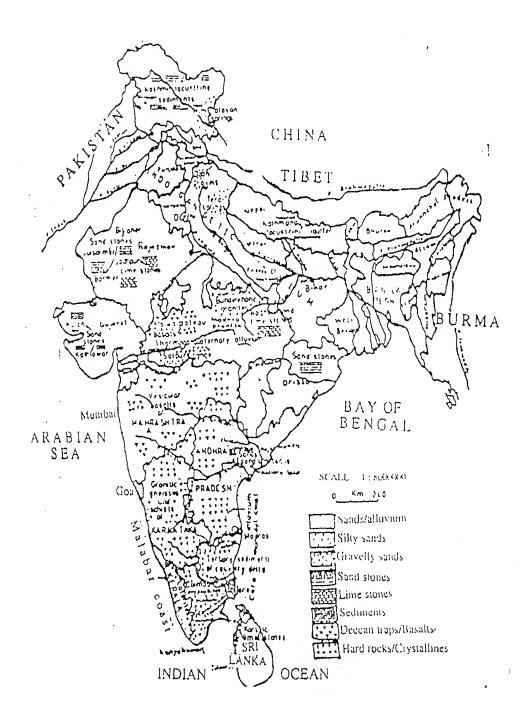


Fig.1.3 Groundwater availability in India

1.5.2 Pre-Cambrian Sedimentary Province

The province comprises of four discrete structural basins containing limestone, shale, sandstone, quartizites and local conglomerates of late precambrain to early palaeozoic age. The basins are: Cuddapah basin covering about 50,000 km² in the greater part of Rayalaseema region of Andhra Pradesh and isolated areas in Karnataka; Raipur basin in Madya Pradesh covering about 40,000 km²; Vindhya basin covering an area of about 100,000 km² in the watersheds of Chambal, Yamuna, Son and Narmada rivers; and the Western Rajasthan basin covering about 20,000 km². The groundwater is generally hard; TDS lies between 200-5000 ppm in Western Rajasthan region while in other 3 regions it is less than 1000 ppm .

1.5.3 Gondwana Sedimentary Province

The rocks of this province range from carboniferous to early cretaceous and are developed along the Godavari, Mahanadi Narmada, Son and Damodar valleys. The water table lies generally at a depth of 30 m or less. Groundwater generally contains less than 1000 ppm of dissolved solids.

1.5.4 Deccan Trap Province

The province occupies an area of about 500,000 km² in Central and Western India covering almost the whole of

Maharashtra and contiguous parts of Madhya Pradesh, Karnataka, Andhra Pradesh, Gujarat and Rajasthan. The groundwater is generally of good quality with total solids less than 1000 ppm, but often brackish to saline in areas underlain by thick black cotton soils.

1.5.5 Cenozic Sedimentary Province

The province comprises of Malabar and Coromandel coasts, coastal fringes of the Saurashtra and Kutch penninsulas, Cambay basin, Rajasthan and a belt of strongly folded rocks in Eastern India. The coastal plains of Saurashtra and Kutch are relatively less productive. Groundwater is also inferior in quality, the TDS range from 2000 to more than 5000 ppm. Groundwater in Cambay basin is saline below 600 m. In Rajasthan TDS ranges between 1000 to 2000 ppm in upland and over 5000 ppm in depressions.

1.5.6 Cenozoic Fault Basin

It includes three discrete fault basins- the Narmada, the Purna and the Tapti vallies. In Narmada and Tapti vallies groundwater contains 100-500 ppm of dissolved solids, but in parts of Purna Valley, it is extremely saline.

1.5.7 Ganga-Brahmaputra Alluvial Province

The province covers an area of about 850,000 km² consisting of vast plains of Ganga and Brahmaputra rivers underlain by late

tertiary and quaternary alluvium with basement surface of hard rock sloping at an average angle of 1 to 3°. This is the most potential and productive groundwater reservoir in India. The groundwater occurs in three distinct physiographic and hydrologic belts: the bhabar, an elongated, 6-10 km wide, steeply sloping belt issuing from the Himalayan mountains; the terai, a 5 to 15 km wide belt southwards of the bhabar and the axial belt covering most part of the province with deposits of Ganga and Brahmaputra rivers and their tributaries. The productivity decreases drastically to the south of the Yamuna river where the aquifers consists of thin impersistent, fine ground sand and silt clay with kankar. The groundwater in the province contains less than 500 ppm of dissolved solids. The freshest water is found in the teraibhabar belt, the mineral content increases progressively southwards. In Agra-Mathura area, the groundwater is brackish to saline with fresh water occurring in some cases.

1.5.8 Himalayan Highland Province

The province includes a group of high-folded and faulted sedimentary rocks extending throughout the northern mountainous part of the country from Kashmir to Arunachal Pradesh. Here the dissolved solid content seldom exceeds 500 ppm.

1.6 Factors Responsible for Groundwater Pollution

Water pollution is alteration in physical, chemical and biological charactersistics of water, which may harm humans and aquatic biota. Although it is more difficult to pollute groundwater than surface water because the soil can either stop the pollutant reaching groundwater or help to reduce its concentration. Many of our activities affect it adversely. Chauhan *et al.*¹² presented an extensive review of groundwater pollution in India from various factors.

In and around urban areas, domestic and industrial effluents ¹³⁻¹⁵ septic tanks¹⁶⁻¹⁷ solid waste refuse dumps¹⁸⁻¹⁹ and their leachate ²⁰⁻²¹ are the potential sources of groundwater pollution, and also accidental spillages may lead to groundwater contamination (fig. 1.4).

In rural areas, where extensive agriculture is done, many natural and man-made factors contribute to groundwater pollution: the extensive use of fertilizers²²⁻²³ pesticides²⁴⁻²⁵ like insecticides, herbicides ²⁶, rodenticides, miticides, processing wastes and animal wastes, etc. contribute to groundwater pollution. Leachates from agricultural land containing nitrates, phosphates and potash move downward with percolating water and join the aquifers below posing danger to the groundwater.

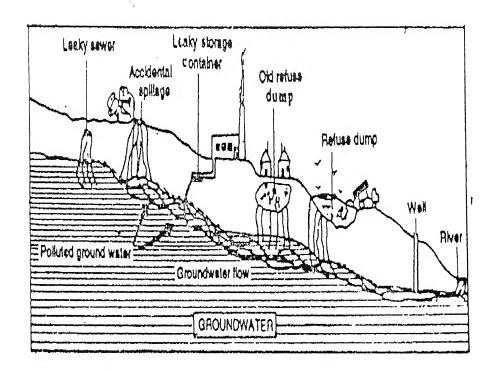


Fig. 1.4 Different sources of groundwater pollution in urban areas

Run-off from urban areas contain large concentrations of oils, greases, nutrients, heavy metals, detergents, etc., that can pass through the soil and pollute groundwater. Raw sewage dumped in shallow soakpits²⁷ and seepage from polluted lake²⁸, pond or stream²⁹ also pollute groundwater. The rainwater may dissolve contaminants from dust and air and join the aquifer below. The infiltration of liquids containing toxic pollutants may cause pollution in well waters.

1.7 Health hazards due to polluted groundwater

The quality of groundwater is of vital importance to human beings for drinking and other domestic purposes. At present nearly one-fifth of all the water drinking and other domestic purpose in the world is obtained from groundwater resources. Groundwater is generally considered pure and is consumed as raw, without any prior treatment.

Polluted groundwater has been the major cause for the spread of epidemic and chronic disease in man. It causes typhoid, jaundice, 'dysentery, diarrhea, tuberculosis, hepatitis, etc. Disastrous cases of groundwater pollution have occurred in most, parts of the world. 3500 people died in New York city due to cholera by the use of polluted well water in 1932. In 1960, the United States Geological Survey observed high content of sulphate, phosphate, nitrate, and chloride in the waters of dug wells of Crasby town in North Dakota. In Brooklyn, USA, saline seawater reached the groundwater leading to contamination.

Quality of Indian groundwater resources has altered considerably in the last few decades. Investigations 30-44 throughout the country, both in rural and urban areas have indicated the rise of various pollutants such as nitrate, fluoride, TDS conductance, heavy metals such as Cu, Cd, Zn, Pb, Ni, Cr, etc., pesticides and MPN counts of bacteria in groundwater leading to various health hazards.

In Medak district of Andhra Pradesh effluents from chemical industries seeped into the subsoils polluting groundwater in 14 vilages around Patancheru Industrial belt. Recently, about 186 tribal villages of Mandala district in Madhya Pradesh have been badly affected by the excess of fluoride in drinking water in nearby villages dark and dirty rendering it unfit for drinking and irrigation.

1.8 Brief Review Of Present Status of pollution

We have a clear idea of how water is essential for life, health, food and human development. It is required for agriculture, industry and sustaining the environment. It determines the quality of our life and land. Despite its importance to basic biological processes and well-being of the living organisms, water is especially vulnerable to pollution, wastage and mismanagement. Human beings always have had an impact on their natural environment, but today's unprecedented population rise, urban expansion, waste disposal, soil erosion, poverty and a variety of water borne diseases provide an urgency that is new in our history.

Environmental pollution is a global phenomenon. Pollution is discussed everywhere-pollution from industry and agriculture, from urban growth and from water development projects such as dams and reservoirs. If not properly planned and managed, all these human activities can have devastating impacts on aquatic ecosystems damaging fisheries, coral reefs, wetlands and watersheds. By far the most serious source of pollution is human

waste, particularly in developing countries. Each year as many as 4 million children⁴⁵ die due to the lack of clean water and proper sanitation. The amount of waste water discharged in the world is expected to double between 1980 and the year 2005. This is in addition to 2 million tons of human excreta which daily pollute the planet's rivers and groundwaters. In Latin America, for instance, upto 98 per cent of sewage is discharged untreated. In Poland 75 per cent of rivers are too contaminated even for industrial use. Two thirds of China's rivers are seriously polluted. In Manila, the capital city of Philippines, 60-70 per cent untreated sewage is discharged into the Pasing river.

Water bodies in India too are receiving enormous quantities of wastes. Total sewage generation⁴⁶ from urban centres grew from 500 crore litres per day in 1947 to around 3000 crore litres per day in 1997. The water requirement of major water consuming industries such as agrobased industries, refineries, petrochemicals, fertilizers and chemical industries has grown from around 1000 lakh litres per day in 1947 to around 40,000 lakh litres per day in 1997, while waste water generation has grown from 700 lakh litres in 1947 to around 30,000 lakh litres per day in 1997. Facilities to treat wastewater are woefully inadequate and where they do exist, they often fail to function properly and remain closed most of the time. Of the 426 large and medium size industries in the region covered by the Ganga Action Plan, 101 do not have adequate pollution control facilities.

The quality of water available to man has received the earliest attention and over the years. Comprehensive national⁴⁷⁻⁵⁷ and international⁵⁸⁻⁶⁵ studies have been carried out. Many standards⁶⁶⁻⁷⁰ have been laid down for drinking water, water used in agriculture and industry as well as liquid effluents from sewage, industrial and other sources.

1.8.1Groundwater Pollution in Indian Urban Areas

The unplanned growth of urban centres in developing and less developed nations have resulted in the development of unplanned settlements without formal water supplies or sanitation. The urban centres with their factories and large populations place an enormous strain on local rivers and aquifers. The groundwater in urban areas is stressed in two ways-

- (a) Over extraction leading to falling water levels.
- (b) Reduced yields and disposal of effluents and wastes leading to quality deterioration.

(i) Pollution due to Seepage from solid Wastes and Sewage

In most developing countries including India, wastes are disposed without critical appraisal of their impact on receiving waters. There are numerous untreated industrial, domestic and

agricultural effluents that deteriorate not only surface water but also groundwater.

Domestic sewage channels are effective potential sources of groundwater contamination specially to shallow groundwater aquifers which are most important sources of water in many cities. These aquifers are also subjected to contamination from natural sources⁷¹. Sharma⁷² et al. Investigated seven water quality parameters of groundwater alongside a sewage channel and waste water lagoon. It is found that almost all the water parameters are abnormally high at places close to wastewater lagoon and along the sewage channel compared to other areas. In less developed countries, major cities seldom have central sewage system. Partially treated or untreated sewage is often discharged to lagoons to unlined channels and to rivers or used to irrigated fields. This results in faecal contamination⁷³⁻⁷⁹ both in shallow water aquifers and in deeper aquifers through poor borehole completions.

Landfills⁸⁰⁻⁸¹ used for refuse dumping⁸² and municipal wastes contribute effectively to the groundwater contamination. According to Jeevanrao and Shantaram,⁸³ the groundwater near refuse dumps in Hyderabad city contains higher values of electrical conductivity, total hardness (TH), dissolved oxygen (DO), biological oxygen demand (BOD), Na, K, Fe and Mn than the water collected from distant wells. Contamination in well waters decreases on going farther from the landfills. Landfill leachate⁸⁴⁻⁹⁰ contributes to groundwater pollution.

Organic and inorganic contents present in crude refuse and products of their decomposition can be leached by water passing through the waste. Organic contents of leachate depend upon decomposition conditions⁹¹. Khan *et al.*,⁹³ studied the different pollutants and degradation patterns of the leachate produced from the refuses of IIT Kharagpur township and reported that different pollutants attained peak values at different times and manifested high rates of self purification. Chauhan *et al.*⁴⁹ studied the characteristics and groundwater pollution potential of solid waste leachate (SWL) and reported that conditions like depth of landfill, moisture application rate and the amount of SW influences the characteristics of leachate.

(ii) Pollution due to Industries

Industrial sites too pose a great threat to groundwater resources. Similar to domestic effluent, industrial effluents ⁹⁴⁻⁹⁶ in less developed countries are often released indiscriminately into the nearest water course or the channel without any prior treatment and contains high inorganic and organic chemicals which can filter down into groundwater. In recent years a number of studies assessing the potential of industrial effluents ⁹⁷⁻¹⁰¹ in groundwater contamination have been carried out in India, most of them held industries responsible for deteriorating groundwater in their respective areas.

(iii) Pollution from other Sources

Undeveloped urban settlement lack underground drainage system. So their domestic sewage is most commonly disposed into septic tanks¹⁰²⁻¹⁰³. The sewage first goes into soak pits whose effluents are discharged into the septic tanks. A septic tank consists of a watertight container which separates liquids from solids and provides a limited amount of organic digestion and some sort of soakage system for disposing off the liquid overflow. Since the effluent from septic tanks is not fully treated, it can cause groundwater pollution.

Leaking storage tanks and pipelines of gasoline and diesel fuel also result in pollution in urban areas of both developed and developing nations. In Western Europe and North America many aquifers are grossly polluted by both light and dense non-aqueous phase liquids¹⁰⁴⁻¹⁰⁵. Finally, groundwater may be polluted through mining and processing of metalliferous and industrial minerals.

1.8.2 Case studies of groundwater Pollution in Indian Cities

Ozha et al. 106 detected excess of nitrate in Churu and Barmer district of Rajasthan and suggested its remedial measures. Srikanth et al. 107 reported high concentrations of heavy metals in the groundwater within 1 km. radius around Hussain Sagar Lake, metallic content decreases beyond this distance, clearly indicating metallic seepage from lake into water. Heavy metal pollution of groundwater is also reported by Zaheeruddin and Shabeer 108 in some parts of Delhi, Singanan and Someshekhara 109 in

Ramneshwaram island, Nag and Das¹¹⁰ in Burdwan district, Pradan and Tiwari¹¹¹ in Rourkela, Singh, Jadon and Mishra¹¹² in Parwanoo area. Tripathi, Shrivastava and Pandaya¹¹³ in Rewa city, etc.

Investigations of Rai and Sharma¹¹⁴ showed number of total aerobic heterotrophic, total coliform and Escherichia coli in well waters sampled from areas of N-W Uttar Pradesh, clearly indicating faecal pollution. Hedge et al. 115 recorded abnormally high concentration of sodium in a well near leather washing point in the Hubli City. The study also correlated TH with TDS and corrosivity ratio, Ravichandran and Pundarikanthan⁷² reported higher values of EC in the groundwater near waste dispoal areas and waterways in Madras city. Rao and Rao¹¹⁷ indicated high TDS values in Vishakhapatnam city. Higher nitrate concentration is reported from places affected by sewage or septic Singh and Kappoor¹¹⁸, Kanpur city tanks. According to groundwater had TDS, TH, Ca²⁺Mg²⁺, NO₃, Cl and coliform values exceeding the permissible limits for drinking purposes.

(a) Fluoride in Groundwater

One of the serious health problems, facing the country is fluorosis involving lakhs of people, arising primarily due to excess of fluoride in drinking water. Fluorosis was first reported by Shortt et al.¹¹⁹ There have been a number of reports on fluorosis from different parts of the country¹²⁰⁻¹²⁷ in recent times. Recently fluoride

ion has also been incriminated as carcinogen and mutagen, though this aspect is not universally accepted 120-130. Sudarshan and Reddy 87 studied the incidence of fluoride in drinking water resources in Sivannagudem area of Andhra Pradesh. Gupta et al 132 reported fluoride in exces in Shamshabad block of Agra causing skeletal and dental fluorosis. A significant increase in fluoride content was found by I.V. Suresh and co. workers 133 in Bhopal water resources. Similarly Nemade and Shrivastava 134 found 2-5 times higher fluoride concentration than WHO standards in Tribal belt of Satpura valley. S.R. Tamta 135 observed a high fluoride content a number of stations in Karnataka and discussed the possible mechanism for concentration of fluoride in groundwater.

(b) Nitrate Pollution of Groundwater

Intense agriculture, often by means of irrigation and associated increasing use of fertilizers and pesticides have been damaging the groundwater quality as observed particularly in the Latin Amercian and South Asian regions where rates of application of nitrogen fertilizers are high, and upto 3 crops a year can be raised by intensive irrigated cultivation. Extensive agriculture with many natural and manmade factors contributes to groundwater pollution. Higher concentrations of nitrates were reported by several workers in India¹³⁶⁻¹⁴⁰ and other parts of the world¹⁴¹⁻¹⁴² due to indiscriminate use of nitrogenous fertilizers. The use of inorganic fertilizers, manures and lime are responsible for the change in natural quality of water in five regions of USA¹⁴³. If the

current nitrogen application as fertilizer is continued, the nitrate concentration in extracted water will continue to rise in the years to come¹⁴⁴.

(c) Pesticide Pollution of Groundwater

Groundwater contamination by persistent organic chemicals in recent years have emerged as a major environmental concern because of the difficulty in evaluating their ecotoxicological effects when these are located beneath the water table. Moreover, when these chemicals are present in groundwater, remedial actions become extremely difficult and expensive. Pesticides are known for their toxicity, lipophilicity and persistence in environment. Although these have been found to contaminate the groundwater in farming regions of industrial nations¹⁴⁵⁻¹⁴⁷ the problem is more acute in tropical third world countries where pesticides are still used in large quantities148-149 because of their effectiveness and low cost. Leaching from agricultural fields is a single source of contamination of groundwater. Pesticide residues have been reported in groundwater of various Indian urban and rural areas. Mohapatra et al. 150 studied groundwater contamination from pesticides in rural areas of the Indo-Gangetic Plan and reported increased residues in July-November half of the year, i.e. in post monsoon period. Cherian and Khophar¹⁵¹ concluded that pesticides pose a major health hazard and threat to life if not handled carefully. They can cause cancer, nervous disorders, dermatitis, etc. Ramachandran et al. 152 Studied nitrate, BHC and DDT concentrations in groundwater of cultivated areas of North Madras. They reported BHC values between 0.16-1.08 ppm and DDT was absent in all samples. Thakkar and Muthal¹⁵³ have used granular activated carbon in pesticide removal from groundwater.

(d) Heavy Metals in Groundwater and Their Speciation

Heavy metals are the constituents of large numbers of industrial, domestic and agricultural discharges. The toxicity of metal and its rate of uptake from solution depends on oxidation state of metal. So it is important to analyse them and study their speciation¹⁵⁴⁻¹⁵⁸ which has become an important tool in assessing environmental contamination and ecotoxicology. Bhand and Chaturvedi¹⁵⁹ carried out speciation studies in the Khan river and reported distribution and variation in dissolved and particulate concentrations of P, Zn and Cd. Itoh et al. 160 studied speciation of trace metals in pond water by liquid chromatography. Steve¹⁶¹ has reviewed with 35 references the importance of metal speciation in many areas of environment. Heavy metal speciation was analysed in soil by Boruvka, et al. 162 to assess metal mobility and bioavailability. Similar other studies¹⁶³⁻¹⁶⁵ were carried out by various workers with respect to speciation of heavy metals in environment.

In fact there is a large volume of literature available on groundwater pollution. Study of pollution is continuous process and man must continuously monitor the quality of groundwater to have a proactive approach to the solution of the problem . Some the recent reported studies¹⁶³⁻¹⁷³ reinforce our point of view.

1.8.3 Potability of Groundwater

With increasing environmental pollution, it is absolutely necessary to ascertain the potability¹⁷⁴⁻¹⁷⁵ of water before it is used for human consumption. Water is one of the major carriers of several diseases of both chemical and bacteriological origins and hence careful assessment of physiochemical quality of water is most essential. Many workers have studied quality of groundwater with respect to physiochemical¹⁷⁶⁻¹⁷⁸ and bacteriological qualities¹²⁷⁻¹³⁰ and found correlations¹⁷⁹⁻¹⁸² among the water quality parameters. It is observed that all physiochemical and bacteriological parameters fluctuated due to seasonal changes¹⁸⁸⁻¹⁸⁹.

1.8.4 Protection of Groundwater resources

Groundwater storage constitutes a vast and almost ubiquitous effort for satisfying water requirements of all kinds. Moreover, additional storage under the surface of soil, if properly utilized, increases the available water resources for future use, water which otherwise be lost through evaporation or run-off. Groundwater recharge 190-192 as either interstitial (matrix) or macropore 193-195 recharge, former allowing solutes to reach the water table faster. A number of remedial action 196-197 could be

taken to ensure non-contaminated supply of groundwater for drinking and other purposes such as-

- 1. Sealing of unused and unprotected wells
- 2. The sanitary maintenance of open wells
- 3. Lining of waste disposal sites
- 4. Modifications of agricultural techniques
- 5. Control of the quality of domestic sewage and industrial discharges into rivers and near groundwater sources.
- 6. Restriction on the use of inorganic fertilizer and pesticides in aquifer recharge area.

1.9 Area and scope of present investigation and analyses undertaken

Although Kanpur appears in the less problematic area in the map of Uttar Pradesh (Fig. 1.5), it is one of the worst cities in India as far as environmental conditions are concerned. All water and noise pollution far exceed the permissible limits. The city is located between north latitude 28°26' and east longitude 80°24' Kanpur metropolis, the largest populated industrial town of the most populated state of Uttar Pradesh includes a host of residential

areas with varied population densities and different strata of society, diversified industrial installation, landfills and agriculture farms. It faces problem of groundwater pollution on a gigantic scale and therefore presents an ideal case for an in-depth study of the problem of ground water pollution in terms of physicochemical parameters and bacteriological contamination to assess the portability of groundwater in various seasons at multifarious locations. In fact, continuous monitoring the quality groundwater of the metro is necessary a take steps improve its qualities. Preventive measures for further elimination of pollutants can also be under taken.

Thus, in order to make on intensive and extensive appraisal of extent and quality of groundwater pollution in Kanpur metro the following procedures were be employed.

Various segments of Kanpur metro classified into different types of residential areas and using a number of sampling stations consisting of hand pumps, dugwells, and jet pumps were identified. The collected samples analysed in the laboratory using standard methods 70-75, 198-203.

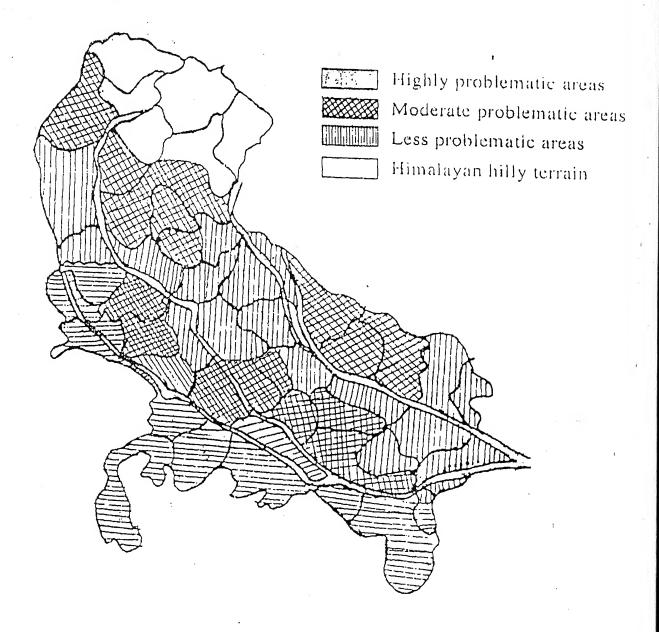


Fig. 1.5 The Groundwater problematic areas& Uttar Pradeshand Uttaranchal

For a comprehensive assessment of physicochemical and bacteriological quality of groundwater, the physicochemical parameters of samples collected in different seasons were evaluated for pH EC, TDS, T.Alk., T.H., Temp. H. and Perm. H. The concentrations of Ca⁺⁺, Mg⁺⁺, SO₄ Cl⁻, F⁻, NO₃, PO₄ Fe⁺⁺, Cu⁺⁺, Zn⁺⁺, Cr⁺⁺⁺, Pb⁺⁺, Mn⁺⁺, Ni⁺⁺ were determined as also the MPN of the each sample.

Objectives

The following objectives were set forth to investigate the groundwater quality and protection measures in Kanpur metro city:

- 1. The groundwater quality in Kanpur Metro with reference to following parameters:
 - (a) Physicochemical and microbiological assessment.
 - (b) Concentration of heavy metals..
- 2. Seasonal variation in groundwater quality of Kanpur Metro.
- 3. Groundwater storage and artificial recharge.
- 4. Suggestions and recommendations for a better management of groundwater resources.

REFERENCES

- 1. Odum, E.P., 1977, Fundamentals of Ecology, Holt Saunders, New York and Eastbowine
- 2. L. Saha D, and Sarkar, S.S. 1991, Chemical quality of water in relation to depth zones. J. Env. Poll. 12 (11) 930-935.
- 3. Driscoll, F.G., 1986, Groundwater and Wells, Johnson Divisions, St. Paul, Minn.
- **4. Scalf, M.R.** *et al.*, 1981, *Mannual of Groundwater Analysing Procedures*, National Well Water Association, Worthington, Ohio
- **5. Waitan, W.C.,** 1970, Groundwater Resource Evaluation, McGraw Hill, New York
- 6. Canter , L.W. & Knox, R.C., Groundwater Pollution Controls', Lewis Chelsea, Mich
- 7. Fairchild, D.M., 1987, Groundwater Qualityand Agricultural Practices, Lewis Chelsea, Mich
- 8. Logan, T.J., 1987, Effect of Conservation Tillage on Groundwater Quality, Lewis Chelsea, Mich
- 9. Hamilton, P.A. & Helsel, D.R. 1995, 'Effects of agriculture on groundwater quality in five regions of United States', Groundwater, 33 (2), March-April
- 10. Shields, E.J., 1985, Pollution Control Engineer's Handbook, Pudvan, Northbook, pp. III

- 11. Trans, C.C.& Etnier, E.L., 1985, Groundwater Pollution', American Association for Advancement of Science, West View, Boulder, Colo
- 12. Chauhan, B.S. et., 1997 'groundwater and its Pollution', Asian J. of Chemistry, 9 (4), 841-844
- 13. Kanan, N. & Rajshekharnan, N., 1991, 'Correlations of water quality parameters of a printing industry effluents in Sivakasi,' Indian J. Environ. Hlth., 33 (3), 330-335
- **14. Sharma, D.R.R.,** et al., 1989, 'Assessment of industrial groundwater pollution potential from correlations of parameteric ratios', **IJEP, 9**(12), 916-917
- **15. Singh, Charanjit,** et al., 1996, 'Toxicity of electroplating effluencts', J of Industrial Pollution Control, **12**(1), 15-19
- 16. Subbarao, C. & Subbarao, N.V., 1995, 'Groundwater quality in a residential colony', Indian J. Environ. Hlth., 37(4), 295-300
- 17. Sharma V.V.J. & Narayanaswamy, 1961, 'Groundwater quality in Vishakhapatnam basin, India', Nat, Air and Soil Pollution,: 16, 317-329
- 18. Rao, K.J. & Shantaram, M.V., 1995, 'groundwater pollution from refuse dumps at Hyderabad', Indian J. Environ. Hlth., 37(3), 197-204
- 19. Olania, M.S. & Saxena, K.L., 1977, 'Groundwater pollution by open refuse dumps at Jaipur,' Indian J. Environ. Htlh., 19, 176-188
- 20. Khan, S.K., Rao, C.U. & Bandhopadhyay, Indian J. Environ. Hlth., 36(4) 248-250

- **21. Chauhan, B.S.** et al., 1998, 'Characteristics and groundwater pollution potential of solis waste leachate', Asian J. of Chemistry, 10(4). (in press)
- 22. Brink, C.V. & Zaadnoordjik, 1985, Groundwater, 33(3)
- 23. Handa, B.K., 1983, Effect of Fertilizer Use on Groundwater in India, Indian Groundwater and Water Resources Planning, UNESCO, 1AH-1AHS, Koblenz
- 24. Cherian, Suman & Khopkar, S.M., 1991, 'Analysis of toxic pollutants pesticides and environmental hazards', IJEP, 11(1)
- 25. Ramachandran, S., et al., 'Nitrate and pesticide concentrations in groundwater of cultivated areas in North Madras', Indian J. Environ. Hlth., 33(4), 421-424
- **26. Singworth, E.A.,** 1965, 'Identification and removal of herbicides and pesticides' Jr. Am. Wat. Wks. Assn., **57**, 1061
- 27. Quasim, S.R. & Burchimal, J.C., 1990, 'Leaching from simulated landgfills', J. Wat. Poll. Cont. Fed., 42(3), 371-379
- 28. Srikanth, R., et al., 1993, 'Lead cadmium and zinc contamination of groundwater around Hussain Sagar Lake, Hyderabad, Indian', Bull. Environ. Contam. Toxicol., 50, 138-143
- 29. Sharma, H.K., et al., 1990, 'groundwater contamination alongside a sewage channel and waste water lagoon', IJEP, 10(8)
- **30. Ozha D.D.,** et al., 1993, 'Nitrate in groundwaters of some districts in Rajasthan', Indian J. Environ. Hlth., **35**(1), 15-19
- 31. Gangal, R.K. & Zutshi, K., 1990, 'Groundwater pollution and the effects of rain near Khetri copper complex', Indian J. environ, Hlth., 33(4), 339-344

- **32. Kumarswamy, N.,** et al., 1997. 'Groundwater quality of a coastal basin in Visabhapatnam-A case study', Indian J. Environ. Hlth., **37**(2), 109-114
- 33. Jain, C.K., Ram, D. & Bhatia, K.K.S., 1996, 'Evaluation of groundwater quality in district Hardwar', IJEP, 16(10), 730-737
- **34. Rajshekhar, C.,** et al., 1994 'Groundwater pollution from unsewered sanitation -A case study in Tirupati', IJEP, **14**(11), 845-847
- **35. Tripathi, I.P.,** et al., 1996, Analysis of trace elements in water from hand pumps of Rewa city', IJEP, **16**(5), 321-327
- **36. Panda, N. & Singh, B.C.,** 1996, 'Trace metals in drinking water form different sources in port of Paradeep', IJEP, **16**(11), 824-827.
- 37. Mahar P.S. and Bithin Datta, 2001 "Optimal Identification of Groundwater Pollution Sources and Parameter Estimations", Journal of water Resources Planning and Management. ASCE, 127(1), 20-29.
- **38. Abdul Jameel A** 2002, 'Evaluation of drinking water quality in Tiruchirapalli, Tamil Nadu. Indian J.Environ.Hlth, 44(2), 108-112 [10Ref.)
- 39. Abraham Beena T. Anirudhan T.S., Sumesh Kumar K.S., 2002, 'Distribution of hydrograp hic parameters and heavy metal ions in river periyar. Nature Env Polln. Techno, 1(2), 161-163, 0203-092 Dept Chem. SNM Coll,
- 40. Biswal SK, Sarangi B, Behera JP, Majhi B, Pradhan S., 2001, 'Effect of thermal power plant ash pond on ground water. Himalaya J. Env. Zoo, 15(1), 35-42 [6 Ref].

- 41. Gangadhara Rao M, Subha Rao C, Prasad NVBSS, Eswara Rao K.S., Murthi D.N., 2001, 'Groundwater salinity in the water logged areas of lower Godavari Delta. Indian J Environ Prot. 21[11],1018-1024 [5 Ref.]
- **42. Garg V.K., Gupta Renuka, Khurana Bharti** 2001, 'Groundwater quality in western zone of Hisar City (Haryana). Indian J. Environ Toxico, 11(2), 58-61 [11 Ref.]
- **43. Kumar A, Siddiqui EN,** 2001, 'Fluoride distribution in groundwater of Ranchi. Indian J Environ Prot, 21(11), 968-975 [34 Ref.]
- 44. Lark B.S., Mahajan R.K., Walia TPS 2002, 'Determination of metals of toxicological sig nificance in sewage irrigated vegetables by using atomic absorption spectrometry and anodic stripping voltammetry' Indian J. Environ Hlth, 44(2), 164-167 [8 Ref.]
- **45. Clayson, Alison,** 1995, 'Water and Sanitation for All: A World Priority', IRC I International Water and Sanitation Center, VROM 95504/h, **11**
- **46.** 'Water Woes', Sep. 29, 1997, Ground realities, The Times of India
- **47. Sharma, V.V.J. & Narayana Swamy, A.,** 1961, 'Groundwater quality in Vishakhapatnam basin, India', Water, Air and oil Pollution, **16**, 17-329
- **48.** Rawal, N.C., 1978, 'Quality of river waters of India', Proc. 47th Res. Session, CBIP, II, Hydraulics, 139-160
- **49. Rathore, J.S.,** et al., 1982, 'Rural water quality-A case study of village Mehsera, 'district Rewa, Technical Report, Rural Division, EPCO, SEB, A.P.S. Univ., Rewar

- 50. Parmar, P.G.; Patel, S.K. & Mody, I.C., 1982, 'Physicochemical and bacteriological quality of water of Bhavnagar municipal swimming pool and its purification system', Acad. Env. Biol., 1(2), 179-185
- 51. Somashekar, R.K. & Ramaswamy, S.N., 1984, 'Biological assessment of water pollution: A study of the river Kanpur', Intn. J. Environ. Studies, 261-267
- **52. Subramanian, V. & Saxena, K.K.,** 1983, 'Hydro geochemistry of groundwater in the Delhi region of India', Proc. Hamburg. Symposium, IAMS, 146, 307-316
- **53. Saha, I.C. & Pandey, B.K.,** 1987, 'Quality of hand pump waters at Bhagalpur', Acta. Ecol., 9, 44-48
- **54. Suryanarayana Raju, P.V.S.,** 1985, 'Some studies on groundwater quality of Movalavanipalem colony', M. Tech. Thesis, Andhra Univ.
- **55. Dayal, G. & Singh, R.P.,** 1991, Heavy metal contamination of groundwater in Agra city (U.P.), India, Proc. Nat. Acad. Sci., India, 61(A), IV
- **56. Gupta, M.K.,** et al., 1994, 'Fluoride in groundwater at Agra', Indian J. Environ. Hlth., 36(1), 43-46
- **57. Reddy, U.V.B.,** et al., 'Hydro geochemistry of Musi river and groundwater, Hyderabad city', IJEP, 15(6), 440-446
- **58. Wilco, L.V.,** 1955, 'Classification and use of irrigation water', U.S. Deptt. of Agr, Circular, 969
- **59.** Navane, R., et al., 1963, 'Nitrogen content of groundwater in southern California', J. Amer. Wat. Wks. Assoc., **55**, 615-619
- 60. William, H. & Walker, I., 1969, 'Groundwater pollution', J. Amer. Wat. Wks. Assoc., 61, 31-40

- **61. Amadi, P.A.,** et al., 1989, 'Hydrogeochemical assessment of groundwater quality in parts of Niger Delta, Nigeria', En v iron. Geol. Wat., **14**,195-202
- **62. Ahel, M.,** 1991, 'Infilteration of organic pollutants into groundwater: Field study in alluvial aquifers of the Sana river', Bull. Environ. Contm. Toxico., 47, 586-593
- 63. Wager, W.S. & Ruchijat, Dj Rosadi, 1991, 'Goundwater resources and groundwater protection in the Bandung basin', Project Rep. 15, Bandung DEG. GEGATI, Project CTA, 108
- **64. Hem, J.D.** 1991, 'Study and interpretation of the chemical characteristics of the natural water', USGS WSP 2254, Scientific Publication, 120-122
- 65. Brink, C.V. & Zaadnoordijk, W.J., 1995, 'Evaluation of groundwater pollution from non-point sources: A case study', Groundwater, 33(3), May-June
- **66. EPA,** 1988, National Revised Primary Drinking Water Regulation, U.S., Environmental Protection Agency, Federal Register, Oct. 5 **48**(194), Part II
- **67. WHO,** 1984, Guidelines for Drinking Water Quality, Recommendations **81** Geneva
- **68.** Indian Council of Medical Research: 1975, Mannual of Quality for Drinking Water Suppolies, Special Report Serial No. 44, New Delhi
- **69. BIS,** 1991, *drinking Water Specifications*, Bureau of Indian Standards, New Delhi, UDC, **621**,1:0031 S, 10500
- **70. EPA Report,** 1976, National Interim Primary Drinking Water Regulation, EPA Publication No. EPA-570/9-76T003

- 71. Pettyjohn, W.A., 1972, Water Quality in a Stressed Environment, Burgess Pub. Co., Minneapolis, U.S.A.
- 72. Sharma, H.K., et al., 1990, 'Groundwater contamination alongside a sewage channel and wastewater laoon', IJEP, 10(8), 583-585
- **73.** Caur, G.F., et al., 1975, 'Water diseases outbreaks in the U.S.', Jr. Amer. Wat. Wks. Assoc., **68**, 420-424
- 74. Godbole, S.H. & Wable, M., 1981, Sanitary survey of public eating places in Pune: Bacteriological examination of drinking water and food samples, Indian J. Environ. Hlth., 23(2), 134-141
- **75. Manja, K.S.,** et al., 1982, 'A simple field test for the detection of faecal pollution in drinking water', Bull. W.H.O., **60**(5), 797-801
- 76. Narayana, K.L. & Shriharirao, P., 1981, 'Warangal well waters- Bacteriological quality', Indian J. Environ. Hlth., 23(2),148-151
- 77. Sutton, S.E. & Mubiana, D., 1989, 'Household water quality in rurqal Zambia', Waterlines, 8, 1, 20-24
- 78. Sutton, S.E., 1994, 'Microbiological quality of groundwater supplies in rural Zambia', Groundwater Quality, ISBN, 0412, 5860, 7, Chapman and Hall
- 79. Mahan, D.; Singh, B.N. & Kumar, R., 21-23 Dec., 1995, 'Bacteriological characteristics and suitability of the grounwater occurring at BHU campus, Varanasi', Bhujal News
- **80. F. Flutoff,** 1984, Regional Office for South East Asia, New Delhi

- 81. Rovers, F.; Fraquhar, A. & Grahame, J., 1973, 'Infilteration and landfills behaviour', J. Amer. Soc. Civil Engg., 99, EE5, 93
- 82. Olaniya, M.S. & Saxena K.L., 1973; Groundwater pollution by open refuse dumps at Jaipur', Indian J. Environ., Hlth. 19, 176-188
- 83. Jeevanrao, K. & shantaram, M.V., 1995, 'Groundwater pollution from refuse dumps at Hyderabad', Indian J. Environ. Hlth., 37(3), 197-204
- 84. Quasin, S.R. & Burchinol, J.C., 1970, 'Leaching from simulated landfills', J. Wat. Pollut. Govt. Fed., 42(3), 371-379
- **85. Das.,** et al., 1977, 'Leachate production at sanitary landfills site', J. Amer. soc. Civil Engg., **103**, EE ₂
- 86. Hans, J.C. & Peter, S., 1982, 'Lysimeters for simulating sanitary landfills', J. Amer. Soc. Civil Engg., 108, EE 5
- 87. Henry, J.G.; Prasad, D. & Young, H., 1987, 'Removal of organics from leachates by anaerobic filter', Wat. Res., 21(11)
- **88. Kennedy, K.J.,** et al., 1989, 'An aerobic treatment of leachate using fixed film and sludge bed systems', J. Wat. Pollut. Cont. Fed., **60**(6)
- 89. Lema. J.M.; Mendez, R. & Blazques, R., 1988, 'Characteristics of landfills leachates and alternatives for their treatment', Water, Air and Soil Pollution, 40, 233-250
- **90. Lin, K.Y.** *et al.*, 1996, *Mobility of copper, zinc and chromium with municipal solid waste leachate in soils'*, Proceedings of National Science and Council, ROC, Part B, **20**, No. 1, 19-25
- 91. Bagchi, A., 1983, J. Envtl,. Eng. 109, 800

- **92. Kahn, S.K.** et al., 1994, 'characteristics of leachates from solid wastes,' Indian J. Environ. Hlth., **36**(4), 248-257
- **93. Chauhan, B.S.,** et al., 1998, 'Characteristics and groundwater pollution potential of solid waste leachate', Asian J. of Chemistry, **10**(4) (In press.)
- 94. Tiwari, T.N. & Mazoor, Ali, 1988, 'correlation among water quality parameters of industrial waste', IJEP, 8(1)
- **95. Tiwari, T.N.,** et al., 1986, 'Correlation among water quality parameters of the groundwater of Meerut district', Acta. Ciencia Indica, **12**(3), 111-113
- 96. Kannan, N. & Rajshekaren, N., 1991, 'Characteristics of match industry effluents in Sivakasi and correlation's among its water quality Parameters', IJEP, 11(3), 193-198
- **97. Tiwari, N.T. & Manzoor Ali,** 1989, Groundwater of Nuzuid town-regression and cluster analysis of water quality parameters', IJEP, **9**(1), 13-18
- 98. Kannan, N. & Rajshekharan, N., 1991, 'Correlations of water quality parameters of a printing industry effluents in Sivakasi', Indian J. Environ. Hlth., 33(3), 330-335
- **99. Sharma, D.R.R.,** et al., 1989, 'Assessment of industrial groundwaters pollution potential form correlation of parmaetric rations', **IJEP, 9**(12), 916-917
- 100. Baruah, A.K., et al., 1995, 'Assessment of groundwater quality around oil installations at Redresser, Assam, India', Ecol. Inv. & Cons., 1(1-4), 43-45
- 101. Singh Charanjit, et al., 1996, 'Toxicity of electroplating effluents', Jr. of Industrial Pollution Control, 12(1), 15-19

- **102. Shekher, C.R.,** et al., 1994, 'Groundwater pollution from unsewered sanitation: A case study in Tirupati', IJEP, **14**(11), 845-847
- 103. Subbarao, C. & Subbarao, N.V., 1995, 'Groundwater quality in a residential colony', Indian J. Environ. Hlth., 37(4), 295-300
- **104. Panda, A.K.,** et al., 1996, 'Seasonal water quality assessment of Jajang iron are mining area', Jr. of Industrial Pollution Control, **12**(1)
- 105. Ratha, D.S., et al., 1992, 'Statistical analysis of groundwater quality of an iron are mining area', Indian J. Environ Hlth., 34(4), 293-300
- 106. Ozha, D.D., et al., 1993, 'Nitrate in groundwater of some districts of Rajasthan', Indian J. Environ. Hlth., 35(1), 15-19
- 107. Srikanth, R., et al., 1993, 'Lead, cadmium, nickel and zinc contamination of groundwater around Hussain Sagar lake, Hyderabad city', Bull. Environ. Cont. Toxicol., 50, 138-143
- 108. Zeheeruddin, S.K. & Shabber, M.S., 1996, 'Heavy metal pollution in parts of Delhi', IJEP, 16(11), 828-830
- 109. Singanan, M. & Shomeshekar, K., 1996, 'trace element analysis of Rameshwaram island groundwater', IJEP, 16(7), 485-486
- 110. Nag, J.K. & Dass, A.K., 1992, 'Metal contents in drinking water-Studies on Burdwan district', IJEP, 12(9), 641-645
- 111. Pradhan, A.K. & Tiwari, T.N., 1991, Groundwater of Rourkela: survey of some trace metals', IJEP, 11(2), 887-889

- 112. Singh T.B., et al., 1994,' Degradation of water and soil quality of Parwanoo area with respect to heavy metals', IJEP, 14(4), 282-287
- 113. Tripathi, I.P. et al., 1996, 'Analysis of trace elements in water from hand pumps of Rewa city', IJEP, 16(5), 321-327
- 114. Rai, J.P.N. & Sharma, J.P., 1995, Bacterial contamination of groundwater in rural areas of N.W. Uttar Pradesh', Indian J. Environ. Hlth., 37(1), 37-41
- 115. Hegde, S.H.; Puranik, S.C. & Abba, A.K., 1992, 'Groundwater quality deterioration in Hubli city area', Indian J. Environ. Hlth., 34(2), 138-142
- 116. Ravi Chandran, S. & Pundarikanthan, N.V. 1991, Studies on groundwater quality of Madras', Indian J. Environ. Hlth., 33(4), 482-487
- 117. Rao, S.N. & Rao, K.V., 1991, Groundwater quality in Visakhapatnam urban area, Andra Pradesh', Indian J. Environ. Hlth., 33(1), 25-30
- 118. Singh, R.P. & Kapoor, R.C., 1989, Groundwater quality of Kanpur city', Proc. Nat. Acad. Sci., India, 59(B), II
- 119. Shrott, H.E. et al., 1937, 'Endemic fluorosis in Nellore district of South Indian', Indian Med. Gaz., 72, 396-398
- **120.** Rammohan Rao, N.Y. et al., 1974, Studies of water quality and incidence of flourish in Andhra Pradesh, Symposium on flourish, 273-284
- **121. Rammohan Rao, N.V.** et at., 1980, Incidence of fluoride in water resources of Andra Prqdesh', geological survey of India, Special Publication No. 1, 451-461

- 122. Nanda, R.S., 1972, 'Fluoride content of north Indian food', Indian J. Med. Res. 60, 1470-82
- 123. Ray, S.K., et al., 1981, 'Prevalence of flourish in rural community near Varanasi', Fluoride, 14, 86-90
- 124. Desai, V.K., et al., 1988, 'Epidemiological study of dental flourish in trebles residing near fluorspar mines', Fluoride, 21(3), 142-148
- 125. Dwarkanath, M. & Subhuram, V., 1991, Incidence of skeletal fluorosis in a small village population, Indian J. environ. Hlth., 33(2), 182-186
- 126. Samal, U.N. & Naik, B.N., 1988, Dental fluorosis in school children in the vicinity of a aluminium factory in India', Fluoride, 21(3), 137-141
- 127. Saralakumara, D. & Rao, P.R., 1993, 'Endemic fluorosis in the village Ralla Anantpuram in Andhra Pradesh: An epidemiological study', Fluoride, 26(3), 177-180
- 128. Grandjean, P., et al., 1992, 'Cancer incidence and mortality in workers exposed to fluoride', J. Nat. Cancer Inst., 84, 1903-1909
- **129. Hamilton, M.,** 1992, 'Water fluoridation: Arisk assessment perspective', Environ. Hlth., **54**(6), 27-32
- **130. Yiamouyiannis, J.A.,** 1993, Fluoridation and cancer, Fluoride, **26**(2), 83-96
- 131 Sudarshan, V. & Reddy, B.R., 1991, 'Pollution of fluride in groundwater and its impact on environment and socio-economic status of the people-A case study in Sivarnagudem area', IJEP, 11(3), 185-192

- 132. Gupta, M.K., et al., 1994, 'Fluoride in groundwater at Agra', Indian J. Environ. Hlth., 36(1), 43-46
- 133. Suresh, I.V., et al., 1996, 'Fluoride concentration in Bhopal water resources', Ecol. Env. & Cons., 2, 11-15
- 134 Nemade, P.V. & Shrivstava, V.S., 1996, 'Fluorides in tribal belts of Stapura valley', IJEP, 16(2), 99-101
- **135 Tamta, S.R.,** 1994, 'Possible mechanism for concentraion of fluoride in groundwater', Bhujal News, 5-11, June
- 136 Lakshamanan, R. & Rao, T.K., 1986, 'Nitrate and fluoride levels in drinking water in twin city of Hyderabad and Secundrabad', Indian J. Environ. Hlth., 28(1), 45
- **137 Joshi, V.A.; Nanati, M.V. & Vaidya, M.V.,** 1989, Indian Wat. Wks. Assoc., XXI, 351
- 138 Choudhary, G.C., 1990, Sci. Cult., 56, 422
- **139 Handa, B.K.,** 1983, 'Effect of fertilizer use on groundwater quality in India', Groundwater in Water Resources Planning UNESCO, IAH-IAHS, Koblenz.
- **140** Bulusu, K.R. & Pande, S.P., 1990, 'Nitrates-a serious threat to groundwater pollution', Bhujal News, 5(2), 34-43
- 141 Fairchild, D., 1987, Groundwater Quality and Agr. Practices, Ed. D. Fairchild, Lewis Publ., Chlse, K.J., 153-174
- 142 Broers, H.C.M., Nitron a Programme to Calculate Nitrate Leaching in Dutch, The Netherlands
- 143 Hamilton, P.A., & Helsel, D.R., March-April, 1995, 'Effects of agriculture on groundwater quality in five regions of the United States', Groundwater, 33(2)

- 144 Brink, C.V. & Zaadnoordijk, W.J., May-June, 1995, 'Evaluation of groundwater contamination form nonpoint sources- A case study', Groundwater, 33(3)
- 145 Brodie, J.E., et al., 1984, 'Residues related to agricultural' chemicals in groundwater of Bedrekin river delta', North Queensland, Environ. Pollut., 88, 187-215
- 146 Carsel, R.F. & Smith, C.N., 1987, 'Impacts of persticides on groundwater contamination', American Chemical Society. Washington D.C., 71-83
- **147 Ahel, M.,** 1991'Infilteration of organic pollutants into groundwater: Field studies in the alluvial aquifer of the Sava river', Bull. Environ. Contam. toxicol., **47**, 586-593
- 148 Agnihotri. N.P., et al. 1994, 'Organochlorine insecticide residues in Ganga river water near Farrukhabad, India', Environ. Monit. Assessment, 30, 105-112
- **149 Handa, B.K.,** 1979, 'Effect of return irrigation flows from irrigated lands on the chemical composition of groundwater from shallow unconfined aquifers' Proc. Wat. Tech., **11**, 337-349
- **MOHAPATRA, N.P.,** et al., 1995, 'Groundwater contamination by organochlorine insecticide residues in a rural area in Indo-Gangetic plain', Env. Monit. Assess., **35**, 155-164
- 151 Cherian, S. & Khopkar, S.M., 1991, 'Analysis of toxic pollutants-Pesticides and environmental hazards', IJEP, 11(1)
- **152 Ramachandran, S.,** et al., 1991, 'Nitrate and pesticide concentration in groundwater of cultivated areas in North Madras', Indian J. Environ. Hlth. **33**(4), 421-424

- 153 Thakkar, N. and Muthal, P.L., 1980, Granular activated carbon in pesticide removal, Indian J. Environ. Hlth., 22(2), 124-129
- 154 Chen, K.Y., et al., 1974, J. Wat. Poll. Cont. Fed., 46, 2663
- 155 Tessiper, A., et al., 1980, Canadian J. Earth Sci., 17, 90
- **156** Kravtzov, V.A., 1991, Okenologiya, 31(4), 671
- **157 Perez, A.S.**, et al., 1993, 'Simultaneous determination of Cu, Fe, Mn and Zn in Bovine river and eustuarinel sediment', Anal. Lett. 26(4), 271.
- **158. Chakraborti, C.L.** *et al.*, 1993, 'Studies on metal speciation in natural environment', Anal. Chem. Acta., 26(1).
- 159. Bhand, S.G. & Chaturvedi, K.K., 1995, 'AAS and ASV in detection and speciation of cations', IJEP, 15 (6), 426-429.
- 160. Itoh, A., et al., 1997, 'Speciation of trace metals in the environment', Chem. Soc. Rev. (Eng.), 26 (4), 291-298.
- 161. Steve, H.J., et al., 1997, 'Heavy metal speciation in polluted soil', Chem. Listy. Czech., 91 (10), 868-870.
- 162. Bourvka, L., et al., 1997, 'Heavy metal speciation in polluted soil', Chem. Listy. Czech., 91(10), 868-870.
- 163. Henze, G., et al., 1997, 'Speciation of arsenaic (V) and arsenic (III) by cathodic stripping voltametry in fresh water samples', resenius J.Anal. Chem. (Eng.), 358(6), 741-744.
- **164. Zeh, P.,** et al., 1997, 'Speciation of uranium in Gorleben groundwaters', Radiochem Acta. Eng., 76(1-2), 37-44.

- 165. Cherian, S., et al., 1992,' Chemical speciation, characterization and impact of metal pollutants an health from aerosols', IJEP, 12 (5), 324-328.
- 166. Mahar, P.S. and Bithin Datta, 2000"Identification of Pollution Sources in Transient Groundwater System" Water Resources Management, 14(3):209-227.
- **167. Das, Amlan and Bithin Datta,** 2001 "Application of Optimization Techniques in Groundwater Quantity and Quality Management."
- 168. Datta B., A. Bale, C Christensen, J. De George, B. Hoyle, G.T. Orlob, L.M. Kavvas, Interim Report: 1988, "Comparison of Statistical Methods Used to Evaluate Groundwater Contamination".
- **169. Lingeswara Rao S.V.,** 2001, "Fluoride toxicity in ground waters of Chittoor district. Indian J. Environ Prot, 21(9) 794-796[4 Ref.].
- 170. Mariappan P., Yegnaraman V. Vasudevan T. 2001, "Estimation of groundwater quality using rainfall- a case study. Indian J. Environ Prot, 21(11), (1012-1017) [13 Ref.)
- 171. Sarma H.P., Bhattacharya K.G. 2001, 'Quality of drinking water of tubewells and municipal supply waters with respect to Na, K, Ca, Mg and Fe in the Darrang district. Indian J. Environ Prot., 21(11), 1006-1011 [14 Ref.]
- 172. Gupta Bharat B, Kumar Sanjay 1991, 'Self-urification of flowing sewage water of Aligarh. Polln Res. 10(4), 209-213 [13 Ref.]
- 173. Ravichandran S., Pundarikanthan NV., 1991 'Studies on ground water quality of Madras. Indian J Environ Hlth, 33 (4), 481-487 [11 Ref.]

- 174. Ravi, V., et al., 1996, 'Water potability studies using multivariate statistical model', IJEP, 16 (9), 685-691.
- 175. Manzoor, A. & Tiwari, T.N., 1988a, 'Multiple regression for rapid monitoring of water quality', J.Ind. Wat. Wks. Assoc., July-Sept., 237-239.
- 176. Kalita, H., et al., 1988, 'Physicochemical quality of water of Andaman and Nicobar group of Islands', Ind. J. Wat. Wks. Assoc., 20(3), 245.
- 177. Patel, M.K. & Tiwari, T.N., 1989, 'Quality of drinking water in some rural areas of Rourkela industrial complex', J. Ind. J.Wat. Wks. Assoc., 21(2), 197-202.
- 178. Bhargava, R.K., et al., 1978, Groundwater quality in Ajmer district, Ind. J. of Env. Hlth., 20(4), 290-302.
- 179. Bhattacharjee, J.W., et al., 1989, 'Bacteriological quality of drinking water in rural India', Ind. J Wat. Wks. Assoc., 21(2), 185-190.
- **180. Garg, D.K.** et al., 1989, 'Study of physicochemical and bacteriological factors of tube wells water- Roorkee city', Adv. Bios. (Spl.), 47.
- **181.** Singh, A and Wadhwani, K., 1987, 'Fungi in relation to physicochemical factors of tube well water', J. Env. Viol., 8 (4), 347-351.
- 182. Gupta, S.C., 1981, 'Evaluation of the quality of well waters in Udaipur district', Indian J. Environ. Hlth., 23(3), 195-207.
- **183. Tiwari, T.N.,** et al.,1986, 'Correlations among water quality parameters of the groundwater of Meerut district', Acta. Env. Indica, 12p(3), 111-113.

- 184. Ali, M. & Tiwari, T.N., 1988, 'Correlations among water quality parameters of some ancient tanks in Sibsagar district (Assam)', Ind. J.Env. Agri., 3(1,2), 1720.
- 185. Tiwari, T.N. & Patel, M.K., 1990, 'Physicochemical parameters of groundwater of Dharwad district- some correlations', IJEP, 10(5), 330-332.
- **186.** Garg, D.K., et al., 1990, 'Correlation among water quality parameters of groundwater-Rorakee city', IJEP,10(5), 355-359.
- 187. Krishna, J.S.R., et al., 1995, 'Monitoring, correlations and water quality index of well waters of Reddigudem Mandal', IJEP, 15 (12), 914-919.
- **188. Garg, D.K.,** et al., 1990, 'Seasonal variations in groundwater quality in Roorkee city', **IJEP, 10**(9), 673-676.
- 189. Kaur, A., et al., 1992, 'Seasonal variability of chemical parameters in drinking water from shallow aquifers', IJEP, 12 (6), 409-415.
- 190. Brown, R.F., et al., 1978, 'Artificial Groundwater Rechange as a Water Management Technique on the Southern High Plans of Texas and New Mexico, Taxas Deptt. Wat. Resour. Rep., 220.
- 191. Sharma, M.L. & Hughes, M.N., 1985, 'Groundwater recharge estimation using chloride, deuterium and oxygen profiles in deep coastal sands of Wetern Australia', J. of Hydrol., 81 (1-2), 93-109.
- 192. Wood, W.W. & Sanford, W.E., 1995, 'Chemical and isotopic methods for quantifying groundwater recharge in regional semi-arid environment', Groundwater, 33(3), 458-468.

- 193. Beven, K. & Germann, P., 1982, 'Macropores and water flow in soils', Wat. Resour. Res., 18(5), 1311-1325.
- 194. Wood, W.W. & Nativ, R., 1994, 'Evidence for macropore flow', Geol. Soc. of Amer., Abstracts with Progm., 26(7), A-390.
- **195. Wood, W.W.** et al., 1997, 'Quantifying macropore recharge: examples from a semia-arid area', Groundwater, 35 (6).
- 196. Binnie and Partners, 1987, 'Management of Aquifer Resources in Metropolitan Lima, Report to SEDAPAL, 105.
- **197. Foster, S. and Hirata, R.,** 1988, 'Groundwater Pollution Risk Assessment-A Methodology Using Available Data, CEPIS and PAHO, Lina, Pern. pp. 78.
- 198. Hyanes, R., 1982, Envtl. Sci. Methods, Champman and Hall, London.
- 199. Kenneth, E.F., 1976, Principles of Envtl. Sci., Mc Graw Hill Book Company, NY, USA.
- 200. Parker, C.R.,1972, Water Analysis by Atomic Absorption Spectroscopy Varian Techtron PVt. Lt., Australia.
- 201. APHA, 1991, Standard Methods for the Examination of Water and Waste Water, 19th Ed., APH Association, Washington DC
- 202. Trivedi, R.K. & Goel, P.K., 1986, Chemical and Biological Methods for Water Pollution Studies, Envtl. Publs., Karad.
- 203. Vermani, O.P. & Narula, A.K.1989, Applied Chemistry
 Theory and Practices, Wiley Eastern Ltd.s





MATERIAL, METHODS AND PROCEDURES

2.1 INTRODUCTION

Protection and management of groundwater quality are emerging as a great public concern in India. People are becoming more conscious about the nature of groundwater and its usage; regarding its future utility which is not only affected by our human activities but also by its current uses of extravagance and over expatiation especially in urban areas. Recently there was a great hue and cry about presence of pesticide residues in bottled mineral water and soft drinks of some brands of international repute. Most of the bottled mineral water is sourced from groundwater, then processed and packed.

A result of urbanization is the increase in demand and creation of potential with possibility of groundwater pollution. A numbers of studies in the past have shown that land use practices have an impact on the quality of groundwater. A similar situation is being encountered in most of the metropolitan cities with growing urban centres¹⁻¹¹

Most of the urban centres are now facing the problem of potable groundwater due to the increasing sources of pollution through domestic and industrial effluents which are directly released into the ground without proper treatment. In addition, presence of waste disposal sites within the limits of the cities and highly polluted waterways create¹² important sources of groundwater pollution. Most landfills^{13,14} throughout the world are simply refuse dumps and receive 90 per cent of the world's solid waste. Leachate^{15,16} from landfills can pollute groundwater as water moves through the filling material. Urban solid wastes usually have a moisture content less than that of field capacity, therefore leachate from a landfill can be minimized if water can be kept away from the landfill material, which in practice is not possible. Extensive use of chemical fertilizers for higher crop yield and weathered produce contribute a lot to degrade the quality of groundwater because not all the nutrients are used by the crops and unused nutrients leach downward to pollute groundwater.

Groundwater contaminated from aforesaid sources is injurious to human beings if it does not satisfy the prescribed drinking water standards. It is, therefore, essential to demarcate the potable and non-potable groundwater zones based on desirable and maximum permissible limits of various physicochemical and biological parameters for implementing necessary remedial measures to prevent occurrence of adverse conditions.

Kanpur, the major industrial town of Uttar Pradesh, is infested with industries like tanneries, cloth mills, foundries,

electrochemical plants, chemical factories, bevergages, etc., Untreated effluents from these sources and domestic sources, not only pollute surface water but also percolate down to groundwater adversely affecting its physicochemical and biological characteristics. So the present research work has undertaken in an attempt to study the extent of diffuse pollution that has threatened the existing groundwater resources and to use the data so obtained in prediction and protection of this invaluable resource. For obvious reasons, continuous monitoring of groundwater must be carried to assess its potability remedial action taken in a pro-active manner.

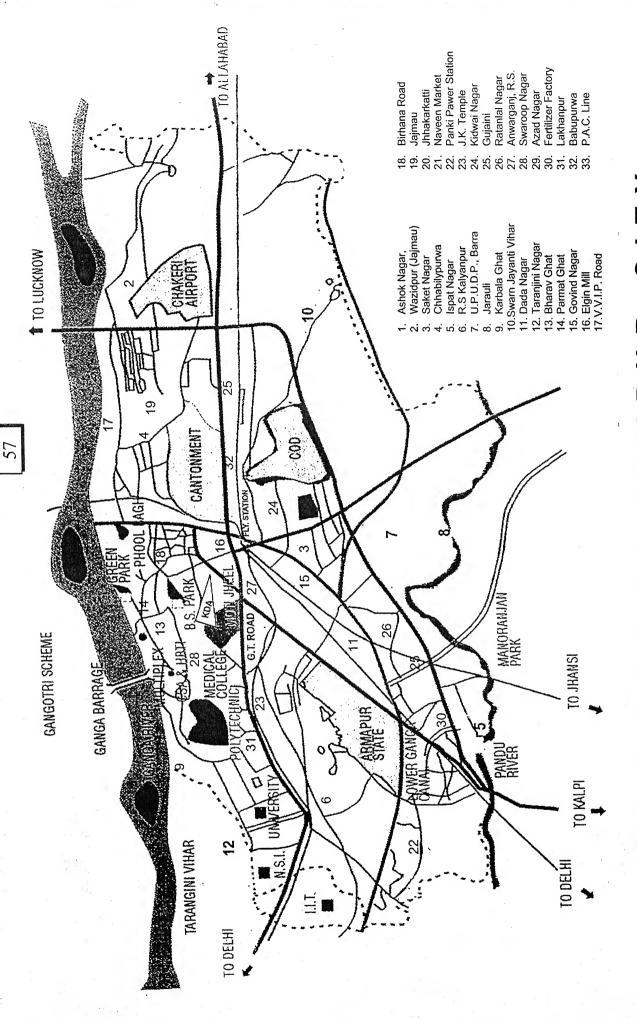
2.2.1 Physiochemical Examination

(i) Area Under Study

The present study covers the entire urban area of Kanpur Metro (Figure 2.0)

(ii) Selection of Sampling Points

After a survey of the city, five types of locations were chosen for collecting groundwater samples. Each type of location had five sampling stations which included mostly the hand pumps, and some dug wells. The sampling points were classified occupationwise using Stratified Random Sampling technique as tabulated below:



KANPUR О П FIG. 2.0 MAP

KANP ഗ COURTE

Residential Areas (RA)

Type of locations	Name of Locations
HIG - I	Tilak Chauraha, Azad Nagar
HIG - II	(United bank of India) Birhana Road
HIG - III	A.H.M. & Duffrin Hospital, Kanpur
HIG - IV	Near Rama Hospital, Lakhanpur
HIG - V	Hallet Chauraha Swaroop Nagar,
MIG - I	Residence of Sri A.B.L. Srivastava, 108/196 Jawahar Nagar, (P. Road)
MIG - II	Residence of Smt. Mangla Sharma 117/148, K-Block Kidwai Nagar
MIG - III	Durga Mandir Govind Nagar
MIG - IV	Residence of Sri K.N.Singh 152/2, Saket Nagar
MIG - V	Residence of Sri Sanjay Yadav, 338C, Kakadeo
LIG - I	Residence of Sri Babu Singh, LIG- 2,Dabauli Tern, Ratan Lal Nagar
LIG - II	Fazalganj Chauraha
LIG - III	212/12 N.L.C. Imran Khan, Babupurwa
LIG - IV	Residence of Sri Ram Charan, LIG, 1367 AV3, Kalyanpur
LIG - V	Purnachand Vidya Niketan Inter College, Barra-1
JJ - I	Residence of Sri Ram Pyare 79 B, Railway Gate Sai Purwa, Jhakarkatti near Bus Stop.
JJ - II	Residence of Sri Bechelal opp.12 Block,
	Kachchi Basti, Govind Nagar

JJ - III	Residence of Sri Ram Surat, Loharan Ka Bhatta behind J.K. Tample
JJ - IV	Residence of Smt. Vijay Laxmi Devi, Shivraj Singh Ka Purwa behind J.K. Temple
JJ - V	Residence of Sri Mohan Pal, Raidash Vihar, Harijan Basti, UCO Bank, Jajmau
IA- I	Residence of Shushil Pandit, LML Chauraha, Shtyam Shivam Photocopy Centre, Side-3
IA- II	At the gate of Hanuman Mandir, Nauraiya Khera
IA- III	Verma Tea Stall 29-B, Dada Nagar
IA- IV	Residence of Kailash Batham 50-A, Vazibpur, Jajmau
IA- V	Vikash Dal Mill, Panki Site-III (Parino Carbation)

(ii) Frequency of Sampling

Samples was done at well planned monthly intervals from May, 2002 to April, 2003.

(iv) Sample Collection

Samples from various groundwater sources were collected in duplicate in one litre plastic bottles, one for physicochemical analysis and other was acidified with conc. HNO, for the analysis of heavy metals. The samples were collected in first week of every month in on the 1st Sunday at around between 8.00 A.M. and 10.00 A.M.



L.I.G.



I.A.



J.J.

Precautions

- 1. Separate samples were taken for physicochemical, heavy metal and biological analysis.
- 2. Sampling bottles were thoroughly cleaned with 50 per cent HNO₃ followed by washing thrice with double distilled water.
- 3. The pump well was flushed for about 5 minutes to ensure a representative sample.
- 4. Before sampling, the sample bottle was rinsed 3 times with the water being collected.
- 5. Different samples were analysed instead of one composite sample.
- 6. For microbial analysis, glass bottle was sterilized in an autoclave.

(v) Preservation Methods Applied in Analysis

To protect samples from changes in composition with ageing due to various interactions, the sample holding time ranges from for pH to one week for metals.

1. Parameters such as pH, total alkalinity and sulphate were recorded within 4 hours after collecting the sample.

- 2. Biological samples were carried in an ice box to the laboratory and were kept in a freezer for preservation, maximum upto 4 days.
- 3. For metallic ions, samples were refrigerated in solutions containing 5 ml. conc. HNO₃ per litre for a period within 7 days.
- 4. Most of the other parameters were analysed within 24 hrs of the sample collection.

2.2.2 Analytical Methods

The collected samples were analysed in the laboratory as per standard methods¹⁹⁻²⁴. The detailed methodology adopted for the analysis of various physicochemical and bacteriological characteristics of groundwater samples is being described in the following lines:

A. pH (Hydrogen ion concentration)

It is measure of concentration of H⁺ ions in water. It was determined with the help of a pHmeter using a glass electrode and reference electrode.

The pHmeter was calibrated by following buffer solutions before taking the sample reading-

- Borax buffer: Dissolved 1.9 g $Na_2B_4O_7$. $10H_2O$ in 500 ml of freshly boiled distilled water after cooling (pH = 9.2)
- 2) Phosphate buffer: Dissolved 1.94g KH₂PO₄ and 1.767 Na₂ HPO₄ in 500 ml of freshly boiled and cooled distilled water (pH = 6.9).
- 3) Phthalate buffer: Dissolved 5.6 g KHC₈H₄O₄ in 500 ml of distilled water (pH = 4.0)

Procedure

After calibrating the pHmeter with one of the above buffer solutions, the electrode assembly was removed and washed with distilled water. Now it was dipped into the water sample and the pH of the sample was read from the meter. The electrodes were always kept in distilled water when not in use.

B. Electrical Conductivity (EC)

Conductance (C) is the reciprocal of electrical resistance (R). The resistance of a conductor with length 1 cm and area of cross section 1 cm² is called specific resistance (ρ). Its unit is ohm cm. The reciprocal of specific resistance is called specific conductance or electrical conductivity (κ). Its units is mhos/cm or μ mhos/cm Conductivity is the conductance of a conductor whose volume is 1cm³. It is a measure of the ability of an aqueous solution to carry electric current. In depends on the presence of ions, their total

concentration, mobility and on the temperature of measurement. It was determined by conductivity measurement method.

Apparatus

- 1) A conductivity cell containing a pair of rigidly mounted electrodes made up of Pt with a coating of Pt-black or carbon.
- 2) An instrument to measure the EC(or resistance) between the electrodes of the cell.

Reagents

- 1) Conductivity water (conductance < 1 μmho/cm).
- 2) 0.01 N standard KC1 solution 0.7456 g of KCl (AR grade) in was dissolved freshly boiled conductivity water and made upto 1000 ml.

Procedure

1) Detection of cell constant: The Conductivity cell was rinsed with at least three portions of 0.01N KCl solution. Temperature of fourth portion was adjusted about to 25°C . Resistance of this portion and the temperature were noted, Cell. x was computed as follows:

 $x = 0.001413 \; R_{KCI} \; [1+0.0191(t-25)]$ where R_{KCI} = measured resistance in ohms and $t = observed \; temperature$

3) **Conductivity measurement:** The cell was rinsed with one or more portions of the sample. Temperature of a final portion was adjusted to about 25°C. Resistance of the sample and temperature were noted.

4) Calculations

$$\kappa = \frac{1,000,000 \text{ x}}{R_{\text{m}} [1 + 0.0191 (t - 25)]}$$

Where κ = Conductivity in μ mhos/cm at 25°C

x= Cell constant in cm⁻¹

 R_m = Measured resistance of sample in ohms

t = Temperature of measurement

C. Total Dissolved Solids (TDS)

The TDS in water samples were estimated as the residue left after the evaporation of filtered sample. The evaporating dishes of capacity 200 ml were strongly heated in an oven for one hour and then weighed after cooling in a desiccator. This was taken as initial mass (A). 100 ml of filtered water samples were taken in pre- weighed evaporating dishes and kept on a water bath at 95°C. After evaporation the residue was heated to 103-105°C in an oven for one hour and weighed (B) finally after cooling in desiccator. The total solids were determined as follows:

Total dissolved solids (mg/l)=
$$\frac{(B-A) \times 1000}{V}$$

where A = Initial mass of evaporating dish in grams

B = Final mass of evaporating dish in grams

V = Volume of water sample taken in ml.

D. Total Alkalinity (T. Alk.)

It is the quantitative ability of water to react with a strong acid at a designated pH. It is primarily a function of carbonate, bicarbonate and hydroxide content in water sample. It was determined by neutralization titration with a strong acid H₂SO₄ using methyl orange and phenolphthalein indicators.

Reagents

- 1. Standard sulphuric acid, 0.1N: 3.0 ml conc. H₂SO₄ was diluted to 1000 ml with distilled water. It was standardized against 0.05N standard Na₂CO₃ solution.
- 2. Sodium carbonate solution, 0.05N: Dissolved 2.5 g dried Na₂CO₃ was dissolved in 1000 ml distilled water.
- 3. Standard sulphuric acid, N/50: Diluted 200 ml 0.1 N standard H₂SO₄ was diluted to 1000 ml with distilled water.
- 4. Methyl orange solution: 50 mg methyl orange was dissolved in 100 ml distilled water.
- 5. Phenolphthalein solution: 50 mg phenolphthalein in 50 ml ethyl alcohol was diluted to 100 ml with boiled and cooled distilled water.

Procedure

100 ml sample was transferred into a titration flash, added 2 drops of Phenolphthalein indicator and titrated against N/50 H₂SO₄ till pink colour just disappeared. The volume of acid consumed (A ml) was recorded. 2-3 drops of methylorange solution was added to the same solution and titrated further until the colour changed from yellow to red. The additional volume of acid consumed (B ml) was recorded.

Calculations

Volume of sample

 $= 100 \, \mathrm{ml}$

Volume of N/50 H_2SO_4 used to Phenolphthalein end point = A ml Additional volume of N/50 H_2SO_4 used to Phenolphthalein end point = B ml

$$N_1V_1 = N_2V_2$$

Sample \equiv N/50 H₂SO₄

$$N_1 = \frac{1}{50} x \frac{A}{100}$$

Strength (as
$$CaCO_3$$
) = $\frac{1}{50}x\frac{A}{100}x500g/l$

Phe alkalinity =
$$\frac{1}{50}x\frac{A}{100}x\frac{50}{100}x1000mg/l$$

= A x 10 ppm

Total alkalinity =
$$\frac{1}{50} x \frac{(A+B)}{100} x 50x 1000 ppm$$

or MeO alkalinity = $(A+B) \times 10 \text{ ppm}$

E. Total Hardness (TH)

The total hardness of water refers to the sum of concentrations of alkaline earth metal cations present in it. It is expressed in terms of mg of CaCO₃ per litre. Calcium and magnesium are the main cations imparting hardness. Iron, manganese and strontium also contribute to hardness but to a lesser extent. Hardness due to the presence of bicarbonates and carbonates of these cations is called temporary hardness and can be removed by boiling. Hardness due to sulphates and chlorides is known as permanent hardness and can not be removed by boiling. The TH was determined by complexometry using EDTA as a titrant.

Reagents

1. Standard hard water (SHW): 1 g anhydrous CaCO₃ was dissolved slowly in small amount of dil. HCI and boiled gently to remove CO₂ heated to dryness on water bath. It was finally dissolved in boiled out distilled water and diluted to 1000 ml of this solution.

 $1ml = 1.00 \text{ mg CaCO}_3$

- 2. EDTA solution (0.01M): 3.7225 g EDTA was dissolved in boiled out distilled water and diluted to 1 litre.
- 3. Erichrome Black -T (EBT) indicator solution: 0.5 g of Erichrome Black-T indicator was dissolved in 15 ml of triethanolamine and 5 ml ethanol.
- 4. Calcium precipitating buffer (pH~8): 6.0 g (NH₄)₂C₂O₄ was dissolved in 100 ml boiled out distilled water. 144g NH₄Cl, was dissolved along with 13 ml conc. NH₃ solution and it was diluted to 1000 ml.
- 5. Ammonium chloride Ammonium hydroxide buffer: 16.9 g
 NH₄Cl was dissolved in some boiled out distilled water. 143
 ml of conc. NH₃ solution was added and diluted to 250 ml.

Procedure

- 1. Standardization of EDTA solution with SHW: 10 ml of SHW (was pipetted out) in a conical flask. To it 40 ml distilled water, 2 ml of buffer and 2 ml of EBT indicator were added. A wine red colour appeared. It was titrated against EDTA solution taken in a burette until colour changed to pure blue. The volume of EDTA used was recorded as A ml. Three concordant readings were taken.
- 2. **Determination of total hardness:** 50 ml of water sample (was pipetted) and 2 ml buffer and 2 drops of EBT indicator solution were added. It was titrated against EDTA till the

wine red colour changed to blue. The volume was recorded as B ml.

3. Determination of temporary and permanent hardness:

250 ml of sample was taken and boiled gently for about 1 hour. It was cooled, filtered and made upto 250 ml. 50 ml of this sample was taken and proceeded as above. The volume of EDTA (C ml) used which corresponds to permanent hardness was recorded.

Calculations

1. Standardization of EDTA solution:

 $1 \text{ ml SHW} \equiv 1 \text{mg CaCO}_3$

A ml EDTA \equiv 10 ml SHW \equiv 10 mg CaCO₃

 $1 \text{ ml EDTA} \equiv 10/\text{A mg CaCO}_3$

2. Total hardness

50 ml hard water \equiv B ml EDTA

 \equiv B (10/A) mgCaCO₃

1 ml hard water $\equiv B \times \frac{10}{A} \times \frac{1}{50}$ mg CaCO₃

1000 ml hard water $\equiv \frac{B}{A} \times 200 \text{ mg CaCO}_3$

∴ TH $\equiv \frac{B}{A} \times 200 \text{ ppm}$

3. Permanent hardness

50 ml hard water ≡ C ml EDTA

$$1000 \text{ ml hard water} ≡ C \times \frac{10}{A} \times \frac{100}{50} \text{ mg CaCO}_3$$

$$≡ A < 200 \text{ mg CaCO}_3$$
∴ Permanent hardness ≡
$$\frac{C}{A} \times 200 \text{ ppm}$$

4. Temporary hardness ≡ Total hardness - Permanent

hardness
$$\equiv \frac{\left(\frac{B}{A} \times 200 - \frac{C}{A} \times 200\right) ppm}{\frac{200}{A} (B-C) ppm}$$

F. Calcium (Ca²⁺)

Calcium occurs in great abundance in all natural waters. It present in water due to passage through or over deposits of limestone, dolomite, gypsum and gypsiferrous shale. It was also determined by the EDTA complexometry.

Reagents

- Standard EDTA solution, 0.01M
 1 ml 0.01 M EDTA = 1 mg CaCO₃ = 0.4008 mg Ca
- 2. Diethylamine
- 3. Calcon indicator solution -Dissolved 0.2 g indicator in 50 ml ethyl alcohol.

Procedure

50~ml of water sample was pipetted out and 3~ml of diethylamine and 4~drops of calcon indicator solution were added . The flask was kept on magnetic stirrer and titrated against standard EDTA solution till the colour changed from pink to pale blue. The volume of EDTA used (D₁ ml) corresponded to the calcium hardness.

Calculations

50 ml hard water ≡
$$D_1$$
 ml EDTA
$$\frac{D_1}{A} = x \ 10 \ \text{mg CO}_3$$
1000 ml hard water ≡ $\frac{D_1}{A} = x \ 10 \ x \frac{1000}{50} \ \text{mg CaCO}_3$

$$= \frac{D_1}{A} = x \ 200$$

$$\therefore \text{ Calcium hardness} = \left(\frac{D_1}{A} = x \ 200\right) \text{ppm}$$

G. Magnesium (Mg²⁺)

It also occurs in all natural waters. Its source lies in rocks. Its abundance or concentration is lower than that of calcium. It was determined by using the EDTA titration.

Reagents

- 1. Standardized EDTA solution.
- 2. Calcium precipitating buffer.

- 3. Ammonium hydroxide Ammonium chloride buffer.
- 4. EBT indicator solution.

Procedure

200 ml of sample was pipetted out and 40 ml calcium precipitating buffer added while constantly stirring the mixture with a glass rod. The ppt. was allowed to settle down for an hour and filtered through a dry funnel fitted with two pieces of Whatmann filter paper No. 42 into a dry flask. 60 ml of the filtrate was measured and added to 50 ml filtered water. 5 ml of NH₄OH-NH₄Cl buffer and 4 drops of EBT indicator solution were then added to titrate against standard EDTA solution. The volume of EDTA used (D₂ ml) corresponds to magnesium hardness.

Calculations

240 ml filtrate \equiv 200 kl hard water

1 ml filtrate \equiv $\frac{200}{240}$ ml hard water

60 ml filtrate \equiv $\frac{200}{240}$ x 60= 50 ml hard water

50 ml hard water \equiv D₂ ml EDTA solution \equiv D₂ x $\frac{10}{A}$ mg CaCO₃

1000 ml hard water \equiv D₂ x $\frac{10}{A}$ x - mg CaCO₃ \therefore Magnesium hardness \equiv $\frac{D_2}{A}$ x 200 ppm

H. Sodium (Na+)

It occurs in most natural waters and ranges from 1 mg to more than 500 mg Na/l. Sodium is determined by the flame photometric method.

Apparatus

I) Flame Photometer Principal: When a solution containing a metallic salt is aspirated into a flame, vapours containing metal atoms are formed. Some of these gaseous metal atoms may be raised to an energy level which is sufficiently high to permit the emission of radiation characteristic of that metal. Flame photometer measures trace amounts of sodium in a direct reading at a wavelength 589 nm.

The lay out of a simple flame photometer is shown below. In figure 2.1.

Air at a given pressure is passed into an atomiser and the suction thus produced draws a solution of the sample into the atomiser, where it joins air stream as a fine mist and passes into the burner. Here in a small mixing chamber, the air meets the fuel gas supplied to the burner at a given pressure and the mixture is burnt. Radiations from the resulting flame passe through a lens, then through an iris diaphragm and finally through an optical filter which permits only radiation characteristics of the element under investigation to pass through the photo cell. The output from the photo cell is measured with a suitable galvanometer.

2) Glassware: All glassware were rinsed with 1:15 HNO, followed by rinsing again with four portions of deionized distilled water.

Reagents

- 1) Deionized distilled water: All the reagents were prepared in deionized distilled water.
- 2) Stock sodium solution: 2.542 g NaCl was dissolved and diluted to 1000 ml by deionised water.
 - 1 ml stock soln ≡ 1 mg Na
- Intermediate sodium solution : 10 ml stock Na solution was diluted to 100 ml whose 1 ml \equiv 100 μ g Na. This was used to prepare calibration curve in sodium range of 1 to 10 mg/l. This solution was further diluted for the preparation of standard curves.

Procedure

A blank and sodium calibration standards in various ranges were prepared. The water sample was taken in a 50 ml beaker and passed through the atomiser using sodium filter keeping the instrument on high sensitivity. Starting with the highest calibration standard and working towards most dilute, emissions at 589 nm were measured. The experiment was repeated for other standards and the sample. A calibration curve

was plotted from the standards and sodium concentration was determined from the curve.

I. Sulphate (SO₄-2)

Sulphates occur in appreciable quantity in all natural wates especially in arid and semi-arid regions where natural waters have high salt content. Sulphate concentration was determined by the gravimetric method by ignition of residue.

Apparatus

- 1) Steam bath.
- 2) Drying oven, equipped with thermostatic control.
- 3) Dessiccator.
- 4) Analytical balance capable of weighing 0.1 mg.
- 5) Filter paper: Ashless, hard finish, sufficiently retentive for fine precipitates.

Reagents

- 1) Methyl red indicator solution: 100 mg methyl red solid salt was dissolved and diluted to 100 ml in distilled water.
- 2) Hydrochloric acid: HCI, 1:1
- 3) Barium chloride solution: 100 g BaCl₂. 2H₂O was dissolved in 1000 ml distilled water. Solution was filtered before use.

4) Silver nitrate -Nitric acid reagent: 8.5 AgNO₃ and 0.5 ml conc. HNO₃ were dissolved in 500 ml distilled water.

Procedure

- 1- Removal of silica: Exces silica (more than 25 mg/l) was removed by evaporating the sample nearly to dryness in a platinum dish on steam bath followed by adding 1 ml HCl and again avaporating to dryness. Drying was completed in an oven at 180°C and again residue was moistened with 2 ml distilled water and 1 ml HCl and evaporated to dryness. Insoluble silica was washed with several small portions of hot distilled water and filtered. Residue was discarded.
- 2- Precipitation of barium sulphate: The sample volume was limited to 150 ml and pH was adjusted to 4.5 to 5.0 using HCI. The sample was heated to boiling and warm BaCl₂ was added slowly until precipitation appeared with continuous stirring. About 2 ml BaCl₂ was added in excess. The ppt was digested at 80-90°C and left overnight.
- 3- Filtration and weighing: The BaSO₄ was transferred on an ashless filter paper and was washed with small portions with warm distilled water until washings were free from chloride. The ppt was filtered, dried and ignited at 800₀C for 1 hour avoiding any loss of ppt particles.

Calculation

$$SO_4 mg/l = \frac{mg BaSo_4 x 411.6}{ml sample}$$

j. Chloride (Cl)

Chloride in drinking water is relatively harmless if present in amounts below 250 ppm. The chloride content of samples was estimated by argentometry (Mohr's method).

Reagents

- 1) Silver nitrate solution 0.02N: 3.3979 AgNO₃, was dissolved and diluted to 1000 ml with boiled out distilled water.
- 2) Potassium chromate solution, 5 per cent.
- 3) Sodium chloride solution 0.1N.

Procedure

71 (double of 35.5) ml of water sample was taken in a conical flask and 2 ml of K₂CrO₄ solution was added. The contents were titrated against silver nitrate solution and the end point was noted (V ml). Persistent red tinge appeared at the end point. Silver nitrate solution was standardized with sodium chloride solution.

Calculation

Chloride content mg/l =
$$\frac{\text{Vml x 35.5 x 1000}}{\text{50 x ml of sample}}$$

K. Fluoride (F)

The fluoride in the water sample was estimated by SPANDS method. The absorbance was measured at 570 nm.

Apparatus

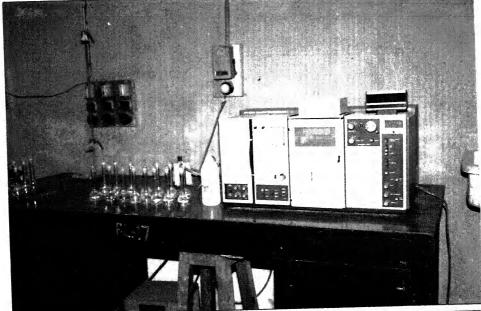
Spectrophotometer

Reagents

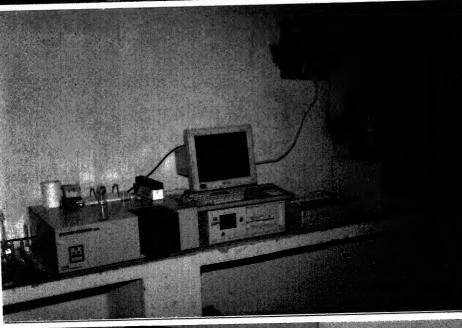
- (1) Stock fluoride solution : 221 mg anhydrous NaF was dissolved in distilled water and diluted to 1000 ml 1 ml \equiv 100 μ g F.
- (2) Standard fluoride solution : 100 ml stock fluoride solution was diluted to 1000 ml with distilled water ; 1 ml \equiv 10 μ g F.
- (3) SPANDS Solution: 958 g of SPANDS i.e. [2-(parasulphophenylazo) 1, 8- dihydroxy-3, 6-naphthalene disulphonate] was dissolved in water Added 350 ml conc. HCl was added and diluted to 500 ml.
- (4) Zirconyl -acid reagent: 133 mg zirconyl octahydrate. ZrOCl₂. 8H₂O was dissolved in about 25 ml distilled water and diluted to 500 ml.
- (5) Zirconyl acid SPANDS reagent : Zirconyl acid and SPANDS reagent were mixed in equal volumes.
- (6) Sodium aresenite solution: 5.0 g Na AsO₂ was dissolved and diluted to 1 litre with distilled water.

Procedure

1. Fluroide standards in the range of 0 to 1.40 mg/I were prepared by diluting appropriate amount of standard



Atomic Absorption Spectrophotometer



U.V. Spectrophotometer



Gas Liquid Chromatograph (GLC)

fluoride solution to 50 ml with distilled water . 10 ml SPANDS - zirconyl acid reagent was added to each standard and was mixed well. Spectrophotometer was calibrated and then absorbance of each standard was noted and standard fluroide-absorbance curve was plotted.

- 2. Sample pretreatment: 1 drop of NaAsO₂ solution was added to the sample.
- 3. Colour development: 10 ml of SPANDS zirconyl acid was added to 50 ml sample, mixed well and absorbance was read immediately. Fluroide content was determined from the standard curve (Calibration curve or caligraph).

L. Nitrate (NO_3)

Nitrate content of the water sample was determined by ultraviolet spectrophotometric method at 220 nm.

Apparatus

- 1. Spectrophotometer.
- 2. $0.45 \mu m$ pore diameter membrane filter.
- 3. Nessler tubes, 50ml

Reagents

- 1. **Nitrate free water:** Deionized water was used to prepare all the reagents.
- 2. Stock nitrate solution: 0.7218 g dried KNO₃ was dissolved and diluted to 100 ml with deionized water.

 $1 \text{ ml} = 100 \mu \text{g NO}_{-3} - \text{N}$

- 3. **Standard nitrate solution**: 50 ml stock nitrate solution was diluted to 500 ml with water whose 1 ml =10µg NO-3 N
- 4. Hydrochloric acid solution, 1N.

Procedure

- 1) 50 ml clear and filtered sample was mixed thoroughly with 1 ml HCl.
- 2) Preparation of Standard Curve: A calibration curve using various calibration standards in the range of 0 to 7 mg NO₃-N/1 by diluting 0,1,2, 4, 7.35 ml to 50 ml of standard nitrate solution.
- 3) Spectrophotometric absorbance was read at 220 nm and NO₃-N concentration was obtained from the calibration curve.

M. Phosphate (PO₄³-)

The phosphate in water was determined by stannous chloride method.

Reagents

- 1) Ammonium molybdate reagent: 25.09 g ammonium molybdate was dissolved in 175 ml distilled water and 280 ml concentrated H₂SO₄ was added to it. The final volume was made to 400 ml by adding distilled water.
- 2) Stannous chloride reagent: 2.5 g of stannous chloride (SnCI₂. 2H₂O) was dissolved in 100 ml glycerol. This

solution was heated in a water bath and stirred with a glass rod to hasten the dissolution. This solution was stable.

3) Standard phosphate solution: This solution was prepared by dissolving 219.5 mg anhydrous potassium dihydrogen phosphate (KH₂PO₄) in 1000 ml distilled water. This contained 50 μg phosphates in 1 ml of solution.10 or 15 ml of this solution was diluted to 5 times. This was standard phosphate solution containing 10mg/l.

1 ml = 0.01 mg phosphate

Sample was taken in a flask, 2 ml of ammonium molybdate and 2-3 drops of stannous chloride solution was added. The contents were thoroughly mixed. A blue colour appeared. After 10 minutes and before 12 minutes the absorbance was recorded with a spectrophotometer at 390 nm. A blank was also prepared in similar fashion using double distilled water. A standard curve was drawn by using different concentration of diluted standard phosphate solution and phosphate concentration in the sample was expressed as mg/l.

2.3 ESTIMATION OF HEAVY METALS

2.3.1 Preliminary Digestion of Metals

5 ml conc., HNO₃ was added to a beaker containing 50-100 ml sample and evaporated on a hot plate and the volume was reduced to about 15-20 ml. Heating and adding conc. HNO₃ was continued until a clear light coloured solution was obtained filtrate was cooled, diluted to 100 ml and mixed thoroughly. This

was used for metal determination as per standard procedure²⁵⁻³⁰

Apparatus

Atomic absorption spectrophotometer

Principle: It measures the decrease in light intensity from a source (hollow cathode lamp) when it passes through a vapour layer of atom of the analyte element. The hallow cathode lamp produces intense electromagnetic radiation with a wavelength exactly the same as that absorbed by the atoms leading to high sensitivity.

Construction: It consists of a light source emitting the line spectrum of the element (hollow cathode lamp), a device for vaporizing the sample (usually a flame) a means of isolating an absorption line (monochromator) and a photoelectric detector with its associated electronic amplifying and measuring equipment as shown in figure 2.2.

Operating Procedure: Hollow cathode lamp (HCL) for the desired element was installed in the instrument and wavelength dial was set according to the standard value and slit width was set according to the manual provided with the equipment. Instrument was turned on for about 20 min to warm up. Air flow rate and current was adjusted according to the manual. Standard solution was aspirated to obtain maximum sensitivity for the element by adjusting nebulizer. Absorbance of this standard was recorded. The subsequent determinations were made to check the consistency of the instrument and finally flame was extinguished by turning off first acetylene flame and then air.

Lamps

Separate lamp (HCL) was used for each element since multielement hollow lamps generally provide lower sensitivity.

(c) Pressure Reducing Valves

(d) Vent

A vent was placed about 15-30 cm above the burner to remove the fumes and vapours from the flame.

2.3.2 Procedure for determination of Heavy Metals

Reagents

- 1. Air: Cleaned and dried through a filter.
- 2. Acetylene: Standard, commercial grade.
- 3. Metal free water: All the reagents and dilutions were made in metal free water.
- 4. Methyl isobutyl ketone (MIBK): Reagent grade MIBK was purified by redistillation before use.
- 5. Ammonium pyrrolidine dithiocarbamate (APDC) solution: 4g APDC was dissolved in 100 ml water.
- 6. Conc. HNO₃
- 7. Standard metal solutions: A series of standard metal solutions of optimum range were prepared by

appropriate dilution of the following stock metal solutions with water containing 1.5 ml conc. HNO₃/l.

(a) Iron: 1 g iron wire was dissolved in 50 ml 1:1 HNO3 and diluted to 1000 ml whose

 $1 \text{ ml} \equiv 1 \text{ mg Fe}.$

(b) Copper: 1g copper metal was dissolved in 15 ml of 1:1 HNO_3 and diluted to 1000 ml.

 $1 \text{ ml} \equiv 1 \text{ mg Cu}$

(c) Cadmium: 1g metal was dissolved in minimum 1:1 HCl and diluted to 1000 ml.

 $1ml \equiv 1 mg Cd$

(d) Chromium: 2.828 g anhyd. K₂Cr₂ O₇ was dissolved in about 200 ml water.1.5 ml conc. HNO₃ and diluted to 1000 ml with water.

 $1 \text{ ml} \equiv 1 \text{ mg Cr}$

(e) Zinc: 1 g zinc metal was dissolved in 20 ml 1:1 HCl and diluted to 1000 ml with water.

 $1ml \equiv 1 mg Zn$

(f) Lead: 1.598 g Pb(NO₃)₂ was dissolved in 20 ml water and diluted to 1000 ml.

 $1 \text{ ml} \equiv 1 \text{mg Pb}$

(g) Manganese: 3.076 mg manganese sulphate was dissolved in 200 ml water and 1.5 ml 1:1 HCl and diluted to 1000 ml with water.

 $1 \text{ ml} \equiv 1 \text{mg Ni}$

(h) Nickel: 1.273g of NiO was dissolved in minimum volume of 10% HCl and diluted to 1000ml with water

1 ml ≡ 1mg Ni

Potassium permanganate solution: 5 per cent solution.

Sodium sulphate, anhydrous.

Water saturated MIBK: MIBK and water were mixed (1:1) in a separatory funnel and shaken. Aqueous layer was withdrawn and MIBK layer was saved.

Procedure

Instrument operation: Water saturated MIBK was aspirated into flame after adjusting the final burner position until flame is similar to that before aspiration of solvent.

Standardization: Three standard metal solutions (100 ml) and 100 ml metal free water were selected and adjusted to pH 3 by 1N HNO₃. Standard metal solution and blank were transferred to a separatory funnel and 1 ml APDC, 10 ml MIBK was added and shaken vigrously. Aqueous layer was drained off and organic extract was directly aspirated into the flame and absorbance was

recorded. A calibration curve was drawn by plotting absorbances of the extracted standards against their concentrations before extraction

Sample analysis: Atomizer was rinsed by aspirating water saturated MIBK and organic extracts obtained by above method was directly aspirated into the flame and absorbance was recorded.

Calculation: Concentration of each metal ion in microgram per litre was obtained by referring to the appropriate calibration curve.

2.4 Bacteriological Examination of Water

Water may contain bacteria which are very small organisms. These may be harmful (pathogenic) or harmless (non - pathogenic) Multiple fermentation was the technique used for MPN (maximum permissible number) count of coliforms. Coliform is a large group of disease causing bacteria that inhabit the intestine of man and animals. The technique involves inoculating the sample and / or its several dilutions in a suitable liquid medium. After the expiry of the incubation period, the tubes are examined for gas production by the coliforms. This is known a presumptive test. Since this reaction may also be produced by the organisms other than coliforms, it is subjected to confirmatory test. For a definite presence of coliform bacteria, the complete test was

carried out. The bacterial density was calculated on the basis of positive and negative combination of tubes using MPN tables.

Apparatus and Materials

- 1. Fermentation tubes: 25 ml, 50 ml
- 2. Inoculation loop: 3 mm diameter of nichrome wire
- 3. Durham vials
- 4. Water bath with a stable
- 5. Microscope
- 6. Incubator
- 7. Petridishes: diameter 10 cm
- 8. Pipettes, bacteriological
- 9. Colony counter

2.4.1 Presumptive test

- 1. Three dilutions (0.10, 0.01 and 0.001) were selected.
- 2. 5 tubes with 10 ml single strength medium and 0.1 ml sample, 5 tubes with 10 ml single strength medium and 0.01 sample, and 5 tubes with 10 ml single strength medium and 0.001 ml sample.

- 3. One Durham vial was placed in each test tube and Mc Conky broth was put into the test tube. The test tubes were sterilized at 121°C for 15 min. Broth was thin meat or fish soup.
- 4. All the water samples were shaken vigorously immediately before removing the sample aliquots to the series of tubes.
- 5. Samples were added to the test tubes selected for the test and mixed thoroughly. Separate pipettes were used for different samples as well as for dilutions.
- 6. Within 30 minutes, all these tubes were placed in an incubator at 35-37°C.
- 7. After 48 hrs these tubes were examined. Those showing gas in the Durham vial recorded as positive (+). The tubes showing + tests were subjected to confirmatory tests as gas production is not the only criterion for a positive test.

2.4.2 Confirmation test

For this Brilliant Green Lactose Bile (BGLB) broth was used.

- 1. Fermentation tubes were prepared with 10 ml BGLB medium and Durham vials. The number of tubes prepared were all that showed +ve test in presumptive test.
- 2. These tubes were incubated at 37°C for 4 hours and the tubes which formed the gas were taken as positive.

2.4.3 Completed test

This test was carried out for tubes showing +ve confirmatory test.

- 1. One or more eosin ethylene blue plates were streaked from each tube showing +ve in confirmatory test in such a way that the colonies are separated by at least 0.6 cm.
- 2. These plates were incubated at 35°C for 24 hours.
- 3. Now these plates were examined for bacterial growth and colony appearance. Well isolated colonies with a dark centre (nucleated) were typical coliform colonies. The colonies that were pink and not nucleated were considered as typical colonies and may belong to the other coliform group.
- 4. Now a coliform colony was isolated from each plate into the tubes of Mc Conkey broth and gas production was reported within 48 hours at 35°C.

2.4.4 MPN method for faecal coliform

Coliforms in water may be derived from the sources other than the faecal matter. So it was found desirable to carry out a separate faecal coliform test for the sample where a doubt from the pollution of human origin arises. Faecal coliforms are defined as gram-negative, non-spore forming rods that ferment lactose in 24 hours at 44.5°C with the production of gas in multiple tube fermentation procedure. The major species in faecal coliform

group is Escherichia coli. The presence of these indicates faecal pollution. For this test, the presumptive test was same as for total coliform. In confirmatory test E. coli medium is used instead of BGLB. The tubes were incubated at 44.5°C in a water bath within 30 minutes after inoculation 24 hours. The tubes were subjected to completed test if gas was produced.

Calculation of most probable numbers (MPN)

The MPN calculation was done by combination of positive and negative results to multi-tube test. The values were calculated from table prescribed by APHA. The MPN/100 ml of sample was calculated by the Thomas formula:

MPN / 100 ml =
$$\frac{\text{Number of positive tubes x 100}}{\sqrt{\frac{\text{ml sample in }}{\text{negative tubes}} x \frac{\text{ml sample in}}{\text{all tubes}}}}$$

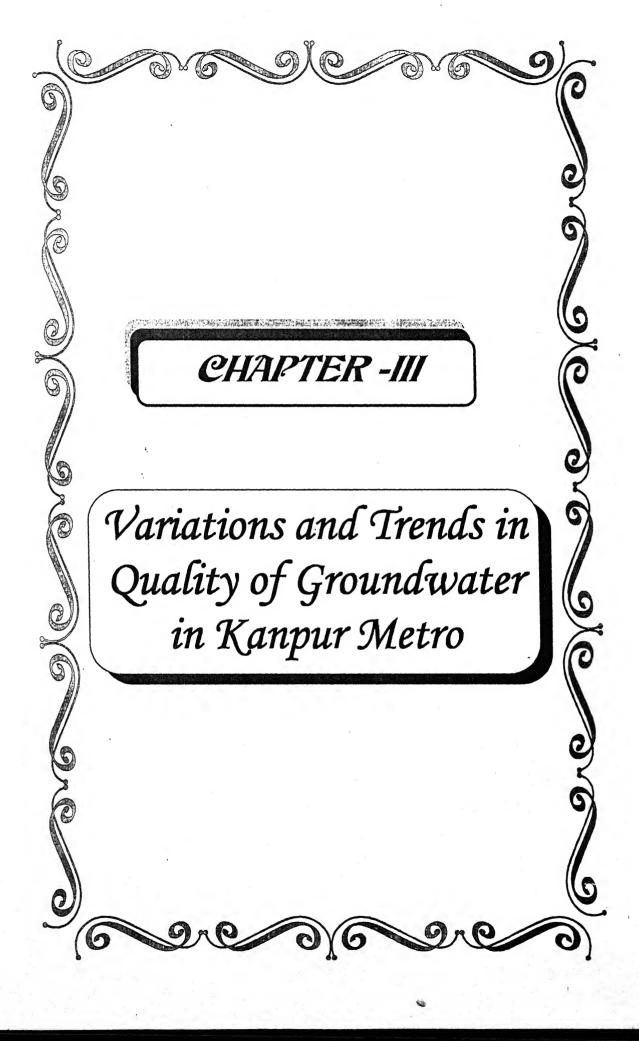
REFERENCES

- (1) Garg VK, Gupta Renuka, Khurana Bharti, 2001, 'Groundwater quality in western zone of Hisar City (Haryana)'. Indian J Environ Toxice, 11(2), 58-61 [11 Ref].
- (2) **Abdul jameel A,** 2002, 'Evaluation of drinking water quality in Tiruchirapalli, Tamil Nadu. Indian J.Environ Hlth, 44(2), 108-112 [10 Ref.].
- (3) Ramaswami, V. & Rajguru. P., 1991, 'Groundwater quality of Tirupur', Indian J. Environ. Hlth., 33(2), 187-191
- (4) **Subbarao, N. & Krishna rao, R.,** 1991, 'Groundwater quality in Vishakhapatnam urban area, Andhra Pradesh', Indian J. Environ. Hlth., **33**(1), 25-30
- (5) **Gupta, A.K. & Saxena, G.C.,** 1996, 'Evaluation of groundwater pollution potential of Agra due to demo-economic factors', IJEP, **16**(6), 419-422
- (6) Ravichandran, S. & Pundarikanthan, 1991, 'Studies on groundwater quality of Madras', Indian J. Environ. Hlth., 33 (4), 481-487
- (7) **Hegde, S.G.,** et al., 1992, 'Groundwater quality deterioration in Hubli city area', Indian j. Environ. Hlth., **34** (2), 138-142
- (8) **Tripathi, L.P.,** et al., 1995, 'Analysis of trace element in water from hand pumps of Rewa city', IJEP, **16** (5), 321-327
- (9) **Suresh, I.V.,** et al., 1996, 'Fluoride concentration in Bhopal water resources', Ecol. Env. & cons., **2** (11-15)
- (10) Sharma, S. & Mathur, P., 1994 'Bacteriological quality of groundwater's in Gwalior', IJEP, 14 (2), 905-907

- (11) **Jain, C.K.,** et al., 1996, 'Groundwater quality in western Üttar Pradesh', Indian J. Environ. Hlth., **38** (2), 105-112
- (12) **Singh, B.,** et al., 1989, 'Quality of drain water of punjab', Indian j. Environ. Hlth., 31 (3), 262-266
- (13) Quasim, S. & Burchinal, J.C., 1970, 'Leaching from simulated landfills', J. Wat. Pollut. Cont.Fed., 42 (3)
- (14) **Das, P.,** et al., 1997, 'Leachate production at sanitary landfill', J. Amer. Soc. Civil Engg., **103** EE2
- (15) **Khan, S.A.,** et al., 1994, 'characteristics of leachates from solid wastes', Indian J. Environ. Hlth., **36** (4), 248-257
- (16) **Chauhan, B.S.,** et al., 1998, 'Characteristics and groundwater pollution potential of solid waste leachate', Asian J. Chemistry, **10** (4)
- (17) **Fairchild, D.,** 1987, 'Groundwater Quality and Agriculture Practices, Ed. Fairchild, Lewis Publs., Chlse, Ml, pp. 153-174
- (18) Guidelines for Drinking Water Quality, 1985. 3, WHO
- (19) **Haynes, R.,** 1982, *Envtl. Sci. Methods*, Champman and Hall, London
- (20) **Kenneth, E.F.**, 1976, *Principles of Envtl. Sci.*, Mc Graw Hill Book Company, NY, USA
- (21) **Parker, C.R.,** 1972, Water Analysis by Atomic Absorption Spectroscopy, Varian Techtron Pvt. Ltd., Australia
- (22) **APHA,** 1991, Standard Methods for the Examination of Water and Waste Water, 19th Ed., APH Association, Washington DC

- (23) **Trivedi, R.K. & Goel, P.K.,** 1986, *Chemical and* Biological Methods for Water Pollution Studies, Envtl. Publs., karad
- (24) **Vermani, O.P. & Narula, A.K.** 1989, Applied Chemistry Theory and Practices, Wiley Eastern Ltd.
- (25) **Perez, A.S.,**et al., 1993, 'Simultaneous determination of Cu, Fe, Mn and Zn in Bovine lines and estuary sediment', Anal. Letl., **26** (4), 271
- (26) Chakraborti, C.L., et al., 1993, 'Studies on metal speciation in natural environment', Anal. Chem. Acta., 26 (1)
- (27) **Bhand, S.G. & Chaturvedi, K.K.,** 1995, 'AAS and ASV in detection and speculation of cations', IJEP, **15** (6), 426-429
- (28) **Itoh, A.,** et al., 1996, Bull. Chem. soc. Japan, **69** (12), 3469-3473
- (29) Steve, H.J., et al., 1997, 'Speculation of trace metals in the environment', Chem. Soc. Rev. (Eng.), 26 (4), 291-298
- (30) Bourvka, L., et al., 1997, 'Heavy metal speculation in polluted soil', Chem. Listy. Czech., 91 (10), 868-870.





CHAPTER III

VARIATIONS AND TRENDS IN QUALITY OF GROUNDWATER IN KANPUR METRO

3.0 INTRODUCTION

Nowadays there is a great awareness of ground water pollution caused by industry, pesticide use and other modes. Hence protection and management of groundwater has become an integral part of pollution control in any part of the world. The quantity and availability of ground water is greatly affected by various human activities specially in the semi urban and urban areas.

Some studies¹⁻¹³ have clearly indicated that land use practices have a measurable impact on quality of ground water. Now Kanpur metro presents one such centre where multifarious activities of its vast populace indulge in activities unintentionally designed to cause groundwater pollution. Indeed, such is the situation in most cities in India.

Once groundwater gets polluted, there is the possibility of it becoming unfit for drinking and other usage. This pollution is obviously the result of increased contamination through domestic and industrial effluents which are directly released into the ground without any treatment at all.

Further, there are landfills in and around the city which are simply wastage and refuse dumps. In most cities, 90% of the city's waste goes into these landfills¹⁴⁻¹⁵. Even pure rainwater moves through this fill material as leachate and pollutes the ground water. One cannot avoid rains. One can create conditions for its better absorption and leaching before it filter through the earth. But water from other sources should not be allowed to go into these landfills to avoid the formation of polluting leachate Similarly, pesticides used for increasing agricultural production should not be allowed to leach through the Land mass to pollute the groundwater.

In this chapter we have reported the results of physicochemical analysis of various ground water samples collected as per procedures already reported¹⁶⁻²⁶ in the previous chapter from specified sites and discussed them in the light of the effect of presence of various pollutants and other parameters on the potability of groundwater available in Kanpur Metro from May 2002 to April 2003.

3.1 Results And Discussion

The detailed monthwise physicochemical a bacterial characteristics and heavy metal concentrates of groundwater in different categories of Kanpur metro have been summarized in tables 3.01 to 3.05 to let us know discuss each of them separately from the point of view of potability and permissible range for the groundwater available in these areas.

96

ig.

Monthly variation in mean values of physicochemical parameters, heavy metal concentration and bacteriological characteristics of ground water in HIG areas of Kanpur Metro from May 2002 to April 2003. Table 3.01

-						-																		_
April 2003	7.72	1006	840	149	290	150	130	140	56.8	35.9	79.3	203	7.60	1.02	10.45	.042	.010	3.66	013	610.	0.010	.016	.39	109
Maicii	7.84	1072	762	140	234	131	101	103	93.2	30.6	88.4	7 22	65.4	.82	3.32	.038	.011	2.7	000	900.	0.014	.014	.32	112
rebruary	7.92	1282	641	125	242	120	120	.120	47.6	29.8	95.35	66.1	00.1	1.09	18.0	.051	.010	4.22	2200	9700.	.006	.019	69.	123
January	7.98	1211	617	135	233	130	051	102	44	29.8	106.1	0.70	84.8	1.36	24.3	.052	.011	3.48	1000	,00.	0.027	.002	96.	126
December	8.06	1175	595	131	203	105	103	86	42	23.8	144.9		121.5	1.86	32.8	820.	.010	3.02	000	.009	.001	.013	1.02	196
November	8.05	1182	592	140	230	140	140	. 80	44	29.1	192.02	1	117.7	1.69	31.10	.057	.011	3.8		.010	0.027	0.010	.93	236
October	8.00	1666	821	155	282		147	135	54.8	35.2	258.4		151.6	1.54	26.4	.049	.062	3.36	20:0	9600.	0.002	.011	.92	228
September	8.04	1600	800	160	096	207	160	100	50	32.8	208.2		182.0	1.73	27.3	.020	.049	3 50	60.0	.005	.0012	600.	.98	261
August	7.98	1.554	816	148	070	210	142	86	44	21.5	142.0	112.0	138.7	1.59	21.02	.018	020	70.0	3.24	900.	.002	.010	1.22	151
July	7.90	1406	962	136	300	740	144	102	47.2	31.1	116.4	1.011	108.3	1.48	16.10	.0212	200		2.8	800.	.002	.019	1.20	130
June	7.88	1346	744	140		730	131	107	42.8	30.3	82.3	07.0	82.4	1.32	12.42	020	000	770.	3.00	.014	.003	.027	1.21	101
May 2002	7.89	1245	719	142	2 1	232	128	104	44	26.74	75.6	0.67	76.8	1.17	11.62	0301	016	010.	2.8	.015	.002	.018		104
Unit	•	uhos/cm	, ma/1	, /9m	111B/1	mg/1	mg/1	mg/1	mg/l		- 0/-	mg/1	mg/l	mg/l	mø/!	: /8	1/9	11/g/11	mg/l	mg/1	mg/l	mg/1	, ma/l	. /9
Variable	Hd	EC	T. C.	1100	I.Alk	Т.Н	Temp.H	Perm.H	Ca++	Ma++	- Quir	S04"	כל	Ĭ.	, ON	3	P.C.	Cu.	Zn ²⁺	Cr3+	Ph2+	Mn2+	N:2+	MIL

P.

Table 3.02

Monthly variation in mean value of physicochemical parameters, heavy metal concentration and bacteriological characteristics of ground water in MIG areas of Kanpur Metro from May 2002 to April 2003.

Ann:1 2003	+	7.79	1476	689	410.30	292	160	157	42.8	44.9	87.3	78.9	1.28	20.42	C L	.053	.029	3.32	.019	0.004	0.018	1.10	315
Moroh	Maich	7.80	1968	732	368.8	274	147	137	58	31.3	100.4	79.4	1.20	22.32	0.40	.043	.036	3.36	0.079	0.004	0.017	86.	499
Coheno	rebruary	7.85	2276	713	576.7	262.30	133	129	49.6	35.5	117.36	81.06	1.29	27.0	, ,	.051	.031	4.02	0.008	0.006	0.019	.73	502
10	January	7.89	2190	758	720.12	257	127	130	40.8	37.6	113.10	98.6	1.86	33.3	313	.062	.053	4.8	0.008	600.0	0.012	.63	492
	December	8.00	2340	713	608.20	240	119	121	45.6	30.6	155.8	137.5	1.76	32.8	0.30	.073	990.	4.01	0.009	0.008	0.019	69.	562
	November	8.05	1940	936	520.88	238	101	137	45.2	30.3	202.80	126.9	1.52	36.90	06:00	.063	.063	4.8	0.022	0.0070	0.015	.93	746
	October	8.10	1564	995	486.00	303	144	159	59.2	37.6	266.4	162.0	1.49	27.03	37.03	.059	.078	4.20	0.019	0.008	0.075	68.	542
	September	8.04	1476	1132	458.30	271	129	142	50.4	35.2	221.3	188.0	1.72	00 10	35.02	.03	.050	4.23	0.012	0.008	0.019	0.96	399
	August	8.05	1256	821	. 413	257	118	139	36.8	40.0	154.0	145.6	1.58		36.9	.027	.040	3.36	0.008	900.0	0.010	1.02	291
	July	7.80	820	786	338.43	242	100	142	37.6	35.9	126.7	109.3	1.56		25.1	.0339	800.	2.89	0.009	0.005	0.025	1.20	178
٠	June	7.72	1268	703	410.00	241	104	137	37.2	35.9	91.8	90.6	1.42		12.84	.039	.013	3.13	0.015	0.004	0.032	1.31	241
	May 2002	7.78	1248	678	432	238	107	131	40	35.5	83.3	83.6	1.38		12.42	.052	.017	3.08	0.020	0.003	0.019	1.31	175
	Unit		uhos/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		. /9	mg/l	mg/l	mg/1	mg/1	mg/l	mp/l	l/am	- /9 /am	/100ml
	Variable	Ha	EC .	TDS	T.Alk	T.H	Temp.H	Perm H	Ca++	Mp++	- POS	5 5	5 1	Υ.,	NO3	Fe ²⁺	Cu2*	Zn2+		Dh2+	Mn2+	N;2+	Coliforn

1× ..

Monthly variation in physicochemical parameters, heavy metal concentration and bacteriological characteristics of ground water in LIG areas of Metro from May 2002 to April 2003. Table 3.03

April 2003	7.04	1501	842	508.3	298	170	128	58.2	36.9	132.3	000	66.3	18.32	1.32	.052	.018	3.98	.036	.052	.071	1.21	306	323
March	7.02	1532	852	543.03	302	691	123	57.6	38.3	102.8	0 70	84.3	1.30	21.20	.059	610.	4.30	.041	620.	.073	.92	644	4/3
February	96.9	1768	890	702.08	292	172	120	56.4	34.2	117.8	910	91.0	1.59	24.4	.061	.029	4.50	.051	.082	.082	.92	707	cne
January	7.09	1817	917	769.38	300	175	125	28	37.6	127.3	0.11	113.6	1.72	26.80	.062	.030	4.20	.062	.082	960.	66	475	475
December	7.42	2190	1091	673.28	289	168	121	59.6	34.02	178.3		142.5	1.80	29.3	620.	.029	4.01	.073	.092	.126	1.12	200	632
November	7.63	2463	1087	618.03	403	261	142	90.09	26.9	218.6		135.9	1.78	36.02	.071	.020	4.8	090.	011	.369	1 20	2011	692
October	7.9	2154	1165	563.43	468	304	164	65.2	30.2	223.00		178.8	1.72	42.30	.052	720.	4.90	.049	.073	.537	1 30	1.04	573
September	7.51	1938	1291	528.60	304	162	142	59.2	37.9	248.3		203.00	1.69	40.28	.038	.059	4.50	.032	.089	.426	100	1.00	453
August	7.39	1613	984	405.3	278	139	139	55.2	34.02	177.3	2:11	158.8	1.78	36.20	.031	.052	3.32	600.	.038	326		2.32	322
Vlul.	7.11	1128	847	379.34	264	117	147	53.6	34.5	136.5	2.001	127.3	1.66	23.96	.0412	.011	2.92	.010	.026	232		2.02	275
June	7.22	1342	863	457	339	198	141	66.8	41.7	149.3	0.241	95.3	1.8	17.13	.0042	010	3.20	020	019	063	200:	1.73	263
May 2002	7.20	1301	828	472.12	324	189	135	54	45.9	150.0	7.601	89.3	1.42	16.32	056	018	3.01	030	004	090	200:	1.62	203
Hait	-	uhos/cm	mg/l	mg/l	mg/l	mg/I	mg/1	mg/]	/8 /8	11.6/1	mg/1	mg/l	mg/l	mø/1	-/9	s/:	11.5/1 ma/l	mg/1	111B/1	1/2/11	IIIB/1	mg/l	/100ml
47 1- 1.1.	variable	EC E	SUL	TAIk	H	Temp.H	Perm H	++50	Can.	MBT	SO4"	Ö	Ĺ	·	1003 1003	LC.		ZIII-		LOZ	Mn.	Ni ²⁺	Coliform

Monthly variation in physicochemical parameters, heavy metal concentration and bacteriological characteristics of ground water in LIG areas of Metro from May 2002 to April 2003. Table 3.03

Anril 2003	coop midu	7.04	1501	842	508.3	298	170	128	58.2	36.9	132.3	88.3	18.32	1.32	.052	.018	3.98	960	000.	.052	.071	1.21	325
March	Marcu	7.02	1532	852	543.03	302	169	123	57.6	38.3	102.8	84.3	1.30	21.20	.059	610.	4.30	170	.041	620.	.073	.92	473
Pohemore	rentary	6.98	1768	890	702.08	292	172	120	56.4	34.2	117.8	91.6	1.59	24.4	.061	.029	4.50	05.1	usu.	.082	.082	.92	505
Louisons	Oamuary	7.09	1817	917	769.38	300	175	125	58	37.6	127.3	113.6	1.72	26.80	.062	.030	4.20	0,0	790.	.082	960'	66.	475
Description	December	7.42	2190	1001	673.28	289	168	121	59.6	34.02	178.3	142.5	1.80	29.3	620.	.029	4.01	000	.073	.092	.126	1.12	632
	November	7.63	2463	1087	618.03	403	261	142	00:09	26.9	218.6	135.9	1.78	36.02	.071	.020	4 8	2:	.060	011	.369	1.20	692
	October	7.9	2154	1165	563.43	468	304	164	65.2	30.2	223.00	178.8	1.72	42.30	.052	077	7 00	4.30	.049	.073	.537	1.32	573
	September	7.51	1938	1291	528.60	304	162	142	59.2	37.9	248.3	203.00	1.69	40.28	038	050:	2000	4.50	.032	680.	.426	1.86	453
	August	7.39	1613	984	405.3	278	139	139	55.2	34.02	177.3	158.8	1.78	36.20	031	1000	200.	3.32	600.	.038	.326	2.32	322
	July	7.11	1128	847	379.34	264	117	147	53.6	34.5	136.5	127.3	1.66	23.06	0419	2170.	110.	2.92	.010	.026	.232	2.02	275
	June	7.22	1342	863	457	339	198	141	66.8	41.7	142.3	95.3	1.8	17.13	0040	2100.	910.	3.20	.020	.019	.063	1.73	263
	May 2002	7.20	1301	828	472.12	324	189	135	54	45.9	159.2	89.3	1.42	16.30	10.92	950.	.018	3.01	.030	.024	090.	1.62	203
	Ifnit	-	uhos/cm	/am	mø/!	mg/1	mg/I	me/l	mg/1	mg/1	mg/1	mg/1	1/am	10	1/gm	mg/1	mg/l	mg/l	mg/l	mg/1	mg/l	mg/1	/100ml
	Waniahla	variable	7 Z	TUS	TAIL	H	Temn H	Derm H	† t-1	Ma++	: 200	5 5	j i	z. (;	NO3.	Fe ²⁺	Cu²:	Zn ²⁺	Cr3+	Pb2+	Mn2+	Ni2+	Coliform

66

Monthly variation in mean value of physicochemical parameters, heavy metal concentration and bacteriological characteristics of ground water in JJ areas of Kanpur Metro from May 2002 to April 2003. Table 3.04

						of and a section	October	November	December	January	February	March	April 2003
Variable	Unit	May 2002	June	July	August	September	20000	101	7 30	7 19	7.2	7.3	7.56
Hd	-	7.5	7.43	7.90	8.12	7.29	8.21	7.31	06.1	61.1	4	5 6	1517
EC	uhos/cm	1333	1367.5	1195	1720	1610	2401	2496	2092	1725	1750	1485	1917
T.D.C.	ma/1	873	918	1009	1059	1342	1220	1096	1116	925	913	698	880
1 A T	mg/]	477.7	456.4	406.3	448	535	575.6	649.4	6.769	760.8	720.4	593.8	540.12
H T	. /8 I/am	470	563	618	809	1050	1165	1420	939	740	570	540	482
Temp.H	mg/1	271	192	281	302	465	503	598	430	325	235	250	235
Perm H	mg/1	199	371	337	507	585	800	822	509	415	335	290	247
- - - -	mg/1	94	117.2	113.2	145.6	148	159.8	142.5	125.6	116.1	104	100	96.8
Mø++	mg/1	57.14	56.6	81.4	108.43	165.2	186.0	258.49	151.8	109.35	75.3	74	58.32
SO4"	mg/I	147.95	162.35	162	190.55	254.6	257.4	229.45	192.85	194.2	142.35	134.8	139.65
יַל פֿל	mg/l	107.6	150.6	205.9	239.7	395.6	451.5	248.7	265.3	206.9	169.3	148.3	133.3
5 6	mg/1	1.54	1.62	1.69	1.67	1.75	1.86	1.94	1.89	1.77	1.61	1.5	1.40
F CN	ma/1	19.3	22.4	35.5	45.95	36.9	40.5	39.9	42.05	40.7	35.1	28.9	25.3
MO3	mø/I	14	.17	.13	0.00	0.11	0.18	0.19	0.21	0.20	0.19	0.17	0.11
Cu ² *	mg/1	0.041	0.045	0.045	0.051	0.053	980.	090.0	0.062	0.052	0.03	0.031	0.25
Zn ²⁺	mg/l	2.6	2.72	2.91	3.04	3.21	4.6	4.92	4.48	4.03	3.98	4.00	3.2
- F-L	mg/1	0.034	0.028	0.018	0.008	0.031	0.051	090'0	0.064	0.068	0.052	0.042	0.036
Ph2+	mg/1	0.016	.017	0.02	0.01	0.05	0.07	0.089	0.079	0.072	0.053	0.035	0.016
Mn ²⁺	mg/1	820.	080	.186	.33	.43	.61	.38	.219	.196	.104	.084	.076
Ni ²⁺	mg/l	1.73	1.81	2.01	4.51	2.00	1.58	1.26	1.06	.93	.89	.99	1.35
Coliform	/100ml	227	275	333	413	487	652	578	542	362	244	215	210

100

Monthly variation in mean value of physicochemical parameters, heavy metal concentration and bacteriological characteristics of ground water in IA areas of Kanpur Metro from May 2002 to April 2003. Table 3.05

February March April 2003	7.42 7.6 7.9	1732 1442 1532	940 890 920	736.8 652.3 573.8	_	863 778 66.8	778	778 415 363	778 415 363	778 415 363 157.2	778 415 363 157.2 93.5	778 415 363 157.2 93.5	778 415 363 157.2 93.5 162.9	778 415 363 157.2 93.5 162.9 204	778 415 363 157.2 93.5 162.9 204 1.63	415 363 157.2 93.5 162.9 204 1.63 34.5	778 415 363 157.2 93.5 162.9 204 1.63 34.5	778 415 363 157.2 93.5 162.9 204 1.63 34.5 .36	778 415 363 157.2 93.5 162.9 204 1.63 34.5 .36	778 415 363 157.2 93.5 162.9 204 1.63 34.5 .36 .076	778 415 363 157.2 93.5 162.9 204 1.63 34.5 .36 .076 3.81	778 415 363 157.2 93.5 162.9 204 1.63 34.5 .36 .076 3.03 0.038	778 415 363 363 157.2 93.5 162.9 204 1.63 34.5 .36 .076 3.03 0.038	778 415 363 157.2 93.5 162.9 1.63 34.5 .36 .076 3.03 0.038 .096	778 415 363 363 157.2 93.5 162.9 204 1.63 3.4.5 3.36 0.038 0.038 0.038
January	7.32	1632	932	756.3	1182	642	540	250.8	60767	157.9	147.3	298	1.82	34.7		.459	0.099	4.30	4.30	0.036	.206	96.	000	700	
December,2	7.12	1992	1142	724.6	1597	949	648	0770	0.4.7	231.3	203.4	388	1.99	36.7	7.00	.428	1.33	4.69	4.70	90.0	.312	1.00	100	381	
November	7.02	2562	1.02	628.5	21.41	1429	1012	201	241.6	200.47	238.3	563	2.10	0 66	33.9	.40	1.03	5.02	4.30	0.092	.402	1.33	000	622	
October	8.3	2663	1273	593.7	2145	1253	807	700	221.2	170.1	289.8	721	2.01		28.2	.329	60.	4.8	4.4	0.036	2697	1.63		716	
September	8.18	2476	1392	543.6	1799	897	000	302	319.6	243	259	588	1.81		26.8	.28	620.	3.22	3.01	0.080	.448	000	7.05	502	
Anonst	8.30	1826	1132	492.3	1341	750	5 6	282	256.4	170.1	203.3	3.8	1.60		23.8	.26	.049	3.12	3.86	0.0062	.334	0 60	2.02	492	
Tulta.	8.70	1256	1012	434 6	777	57.0	010	399	190.8	121.5	187.5	281	1.73		26.3	.22	.013	3.01	3.01	0.032	.138	0.10	71.7	304	
- Inn	7.65	1393	670	456.4	780	765	cot	324	136.6	92.34	176.8	203	1.76		27.3	.30	.014	2.87	3.9	0.014	.092		1.93	283	
Mos. 2000	May 2002	1363	917	783.3	009	022	3/4	240	148.8	90.3	138.6	114.0	1 66	20.1	22.7	.32	.012	2.8	2.81	0.014	.082		1.82	240	-
7. 1.1	Unit	my sodii	1) bar	11/g/1	11/8/11	mg/1	mg/1	mg/l	mg/l	mg/1	mg/l	mg/1	1/2000	11/8/11	mg/1	mg/l	mg/1	mg/l	//sm	. /g	Por	. /9,,,	mg/l	/100ml	
	Variable	Pri Pri	2 6	SUI	I.AIK	T.H	Тетр.н	Perm.H	Ca++	Mg++	304	; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ;	5	ír,	NO3	Fe2+	Cu2+	7.n2+	11 5	Dh2+	Man	THAT	Ni2+	Coliform	1

3.1.01 pH Standard Range 6.5 TO 8.5

At pH 7, water is completely neutral. pH above 7 makes the water alkaline while below 7 makes it acidic. Indeed, it is measure of presence of H⁺ and OH⁻ ions in water. If the pH is below or above the standard range, it affects the mucous membrane and even the water supply system itself as highly acidic or alkaline water has a tendency to attack the material of the supply line. Hence it is desirable that the ground water has pH within the standard range.

It has been observed that the pH range in the five residential areas under investigation lies between 7.04 and 8.7. It is definitely safe from the point of view of potability and plant growth as well. It fact, lightly alkaline water is better for plant growth compared to acidic water (pH< 7.0). The individual range of pH values in different areas is summarized below.

Residential Areas	pH ra	nge	Annual mean
	Lowest	Highest	muai moan
(a) HIG	7.72	8.06	7.19
(b) MIG	7.72	8.05	8.02
(c) LIG	7.02	7.9	7.41
(d) JJ	7.19	8.21	8.4
(e) Industrial area	7.30	8.70	7.9

It goes without saying that the pH of groundwater over the year in al the five types residential areas is well within the desirable range. At the risk of repetition, it must be stated that pH value is a vital indication of quality of groundwater. Greater/lower pH than the desirable range affects the growth of plants and soil micro organisms in addition to affecting the potability properties.

The presence of carbon dioxide, carbonates and bicarbonates in addition to salts of heavier metals (only marginal contribution) control the pH of water. Thus while presence of considerable amounts of dissolved CO₂ decrease pH, the presence of CaCO₃ tends to increase the pH. Temperature also has a role to play in variation of pH to a small extent. Thus, a 25°C change in temperature causes is decrease in pH by 0.45 units as per studies made by Kataria.

3.1.02 Alkalinity

Permissible maximum limit = 200 mg/1 or ppm

It is related the pH value and is a measure of ability of water to neutralize an acid. The presence of carbonates, borates, silicates, and phosphates and traces of hydroxides of sodium and potassium in ground water are responsible for the alkalinity. It is mainly the bicarbonates which are responsible for alkalinity for they are present in considerable amounts in soil.

The alkalinity range of various categories of areas elected for the present studies are given below:

Residential Areas	T.Alk.	(mg/1)	Annual Mean
Residential Aleas	Lowest	Highest	Alliuai meali
HIG	125	160	152.25
MIG	396.8	720.12	605.40
LIG	379.34	702.08	668.55
JJ	406.3	760.8	645.8
IA	434.6	756.3	552.55

It can be concluded that the lowest mean value was found for the HIG areas and the highest for the industrial area. It is definitely on the higher side. It needs correction through not a cause of concern.

3.1.03 Electrical Conductivity (EC):

Maximum permissible limit 400μ mhos/cm

Greater is the concentration of ions, greater is EC and vice versa. Greater EC also means the there is greater salinity affecting the taste and hence acceptability of groundwater by general populace. High EC values also make water unsuitable for irrigation, boilers etc.

The mean EC values of groundwater samples collected round the year are summarized below.

Residential Areas	EC (μmh	os/cm)	Annual Mean
Residential Aleas	Lowest	Highest	minual Moan
HIG	1006	1666	1395
MIG	820	2276	1651.8
LIG	1128	2463	1729
JJ	1195	2496	1724.2
Industrial	1363	2663	1822

The mean value of industrial area is the highest. It may be attributed to large amount of industrial waste seeping into ground to contaminate water with heavy metal ions and anions.

It is worthwhile to recall the definition of electrical conductivity. It is a measure of ability of a substances, solid or liquid to conduct electric current it determines extent of dissolved content in the case of groundwater. Hence we indirectly get an idea of rough estimate of presence of minerals of the basis of E.C. of groundwater sample.

3.1.04 Total Dissolved Solids (TDS):

Maximum permissible limit = 500 mg/l.

In groundwater, salts such as carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates etc. of metals such as calcium, magnesium, potassium manganese etc in addition to some organic matter and other particles constitute the total dissolved impurities. As already stated for EC, high value of TDS affects the taste of water and makes it unsuitable for boilers, heaters and cooking utensils on account of its ability to produce scales on the walls of containers. In our present investigations the mean values of TDS found in various localities are being listed below:

Residential Areas	TD	S (mg/1)	Annual Mean
Residential Aleas	Lowest	Highest	Annual Mean
HIG	592	840	720
MIG	678	1132	804.6
LÍG	828	1291	551.6
JJ	869	1342	1018.3
Industrial	890	1392	1052

The general nature or salinity of groundwater is reflected by the extent of TDS present. TDS of more than 500 mg/l make the water undesirable for drinking purposes. Our investigations have revealed that the TDS in all the five types of residential areas under study is more than the desirable limits. Water with high TDS, besides, being unpotable, causes adverse physiological reaction in humans specially those not accustomed to its use. Efforts must be made to reduce TDS in groundwater before it is used. Some of the effective ways of removing TDS include solar distillation, reverse osmosis, ion-exchange etc.

It is notable here that maximum TDS was found in ground water samples collected from JJ and industrial area where it is as high as 1342 and 1392 mg/l in some cases. Thus, the poorer sections of society are more vulnerable to effects of high TDS. It has been always so in India.

3.1.05 Total Hardness

Maximum permissible limit 300 mg/L

Since the high school level, we get to know about hardness of water which is a measure of its ability to react with soap to produce lather. More specifically, the hardness of water is due the presence of a complex mixture of cations and anions in water. The principal cations causing hardness are Ca++ and Mg++ but others such as Fe³⁺ Sn²⁺, Ba⁺⁺, Mn⁺⁺ etc. also make measurable contribution. The degree of hardness may be expressed in terms

of equivalent calcium carbonate concentration as per Bobbit and Donald²⁸. Thus, the American Geologic Survey has defined varying degree of hardness as follows:

TH as	Degree of hardness
equivalent CaCO3 (mg/l)	
upto 55	Soft water
56-100	Slightly hard water
101-200	Moderate hard water
201-500	Very hard water

Our studies have revealed the following mean figures for total hardness in the five types of residential areas during the year under study.

Residential Areas	TH (1	ng/1)	Annual Mean
	Lowest	Highest	
HIG	203	290	141.8
MIG	203	292	218.5
LIG	278	468	221.7
JJ	470	1420	471.7
Industrial	622	2441	589.6

Thus, we find that TH of ground water in HIG and MIG areas is well within the prescribed limits. It is slightly greater in LIG but there is no cause for alarm. However, in the JJ and industrial areas it is alarmingly high. Water with excess hardness is known to cause heart diseases and kidney problems. It would be worth

while to carry out a medical examination of the population of the areas from this point of view. Water with excess TH causes scaling in hot water pipes in boilers, water heaters and household appliances. The consumption of soap also increases as one gets lesser lather for bathing and washing purposes.

Minimum permissible limit of Ca++ = 75 mg/1

Minimum permissible limit of Mg++=30 mg/1

Indeed, it is these two ions which are mainly responsible for total hardness of water. These metals present in rocks and slowly leach through to groundwater. Sewage lines and industrial effluents also contain these metals which get seeped through to the ground water. In our study areas, the mean concentrations of these metal ion as present in ground water are as follows:

Residential Areas		ration of mg/1	Annual Mean
	Lowest	Highest	
HIG	42	56.8	508
MIG	36.8	59.2	45
LIG	54	66.8	61.8
JJ	94 .	159.8	121.8
Industrial	136.6	256.4	211.5

The presence of calcium in groundwater—in almost all areas under investigation is there found to be reasonably suitable except the JJ clusters and the industrial areas.

Residential Areas	Concentration of Mg mg/1		Annual Mean
	Lowest	Highest	
HIG	26.7	35.9	29.72
MIG	30.6	44.9	35.8
LIG	26.3	45.9	36
JJ	56.6	259.5	144.7
Industrial	90.3	231.3	169

Except perhaps the HIG areas the concentration of Mg in groundwater of all the areas under study is above the permissible limit. The worst affected are the LIG and JJ colonies.

3.1.06 Sulphate

Maximum permissible limit 150mg/l

The presence sulphate ions beyond the maximum permissible limit has been known to cause gastro intestinal disorders and act as laxative if magnesium is also present in considerable amounts. It may also cause respiratory diseases. In the present investigations the data obtained for sulphate presence in groundwater is presented below:

Residential Areas		Concentration of SO ⁻⁴ mg/1	
	Lowest	Highest	
HIG	75.6	258.4	132.4
MIG	83.3	266.0	143.3
LIG	102.0	248.3	163.3
JJ	134.8	257.4	197
Industrial	135.6	287.8	194.7

The desirable limit 150 mg/l for sulphate in groundwater maybe safely extended to 400 if, mg present does not exceed 30 mg/l. However, our studies indicate that almost all the areas under study have Mg concentration over 30 mg/l. Therefore, the concentration of sulphate in ground water in all the samples appears greater than required prescribed limit. Sulphate has only marginal effect on the taste of water as compared to chlorides and carbonates.

3.1.07 Chloride

Max. Permissible limit =250 mg/l

The presence of chloride in groundwater may to attributed to presence of salt deposits below the soil, which dissolve in water in course of time. More chloride may be added to natural ground water from leachate of refuse from sewage, oil well drilling and chemical industries near the coastal areas; sea water may also seep to the groundwater to enrich the chloride content.

In our present studies, the chloride concentration in various residential areas was determine as follows during the year under investigation.

Residential Areas	Concentration of al Areas chloride mg/l		Annual Mean
	Lowest	Highest	
HIG	65.4	182.0	102.00
MIG	79.4	188.0	115
LIG	84.2	203.0	129
JJ	107.6	451.5	410
Industrial	114.0	721.0	352

The results obtained are rather disturbing. Almost all types of residential areas have chloride concentration in the danger Zone. The trend worsens as one moves from HIG to Industrial localities via MIG an LIG in the order stated. In fact nature of the extent of presence of chloride in ground water may be subdivided mite the following zone.

Conc. of Chloride (mg/l)	Zone
<100	Safe
100-150	Tolerable
150-200	Less tolerable
200-250	Intolerable
<250	Hazardous to health

From this point of view, the ground water quality of Kanpur metro leaves much to be desired. Chloride does not enter ion exchange process and is a strong oxidizing agent. Chloride imparts salty test to water. Non-habituals drinking high chloride content water may suffer from intestinal problems. High chloride content may also be the cause of corrosion in structures. It has a deleterious effect on crops as well.

3.1.08 Fluoride

Safe Limit 0.6 to 1.2 mg/l

The management of quality of water involves the determination of fluoride concentrations on account of its effect on health if present in improper amounts.

If the fluoride level is below .06 mg/l the water may cause dental caries. In the right amounts, the fluoride can maintain the tooth enamel. However, excessive amounts of fluorides cause health problems for the consumer. Thus, the consumer may suffer from dental and skeletal fluorosis accompanied by neurological complications and digestive disorders. The bone becomes brittle and is liable to fracture on slight impact Chronic fluorosis may result in loss of weight, anorexia, anaemia and cathexia³⁰ Excess fluoride in plants produces injuries to leaf tips and margins³¹. Fish in water containing excess fluorid may die due asphyxiation.

The cause of excess fluoride in ground water may be attributed to the presence fluorides in rocks. One is helpless if such is the case. But the environmental pollution to can contribute towards increase in concentration of fluoride in ground water. Various industries such as manufacturing glass steel, electroplating, aluminium extraction etc. have effluents which if left untreated, cause fluoride seep down to ground water.

In our present investigations, the fluoride non concentration found in different residential areas are summarised below:

Residential Areas	Concentration of fluoride mg/l Lowest Highest		Annual Mean
HIG	0.82	1.86	1.38
MIG	120	1.86	1.5
LIG	1.30	1.72	1.6
JJ	1.50	1.94	1.68
Industrial	1.53	2.10	1.78

It is disturbing to find that the mean values in all the areas are above the safe limit. Only the HIG localities have an advantage in so far as having fluoride concentrations marginally below the safe limit. Nowhere, in fact not a single sample contains less than 0.6 mg/l of fluoride indicating ruling out the formation dental caries on this account.

3.1.09 Nitrate

Maximum Permissible limit 45 mg/l

The presence of nitrate in groundwater may be attributed to a number of sources. The main among them are geological, anthropogenic and soil nitrogen. Nitrate in groundwater from geological source includes rocks, fossil fuels and nitrate deposits; man made sources of nitrate in groundwater are mainly industrial and agricultural in nature.

It has been reported that presence of excess nitrate in drinking water causes methaemoglobinemia and even cancer in isolated case³²⁻³³. Nitrate can react with haemoglobin of the blood to convert it into methaemoglobin which results in anorexia and finally death. Nitrates in water may be converted into N-nitroso compounds following a series of reactions. These compounds act as carcinogenic agents to cause stomach cancer.

The present investigations results for May 2002 to April 2003 on occurrence of nitrate in groundwater of Kanpur Metro are summarised below:

Residential Areas	Concentration of nitrate mg/l		Annual mean
	Min.	Max.	
HIG	10.45	32.8	19.5
MIG	12.84	37.03	27.5
LIG	16.32	40.28	27.6
JJ ,	19.3	42.05	34.3
Industrial	22.7	35.5	30.2

In the cause of nitrate, the metro is fortunate to have the concentration below the prescribed limit of 45 mg/l. in all residential areas However, some samples in LIG and JJ cluster are too close to the maximum limit to cause comfort. It needs looking into and remedial action taken.

3.1.10 Iron

Maximum permissible limit 0.3 mg/1.

Iron present in various strata of earth gets dissolved in seeping waters to reach the storage level. Iron may also get into water due to corrosion of iron pipes utilized for pumping out the groundwater.

The present investigation have lead up to the determination following levels of presence of iron in groundwater.

Residential Areas	Concentration of iron mg/1		Annual mean
110011011111111111111111111111111111111	Min.	Max.	
HIG	0.018	0.078	0.04
MIG	0.027	0.059	0.48
LIG	0.031	0.079	.051
JJ	0.01	0.19	.15
Industrial	0.22	0.39	.29

Most of the areas covered by the investigations have the presence of iron in acceptable proportion. Barring a few samples in Industrial area, there is no cause for concern on this count.

Beyond the prescribed limit of 0.3 mg/l, iron has effect on colour and taste of water besides promoting iron bacteria. Other studies have also indicated that in most towns of India and specially Uttar Pradesh, the iron content is usually within safe limits and it exceeds the safe limit in areas adjoining rivers, lakes and industries such electroplating and waste dumps where there is every possibility of its leaching down to water table from the wastage.

3.1.11 Copper

Maximum prescribed limit

1.0 mg/.1

Indeed, copper in traces in an essential requirement for human beings who need about 2.0 mg. each daily. However, its excess taken in any form, is injurious to health. It is toxic to even plants and algae at higher levels.

In our investigations, the copper concentration determined as per procedure already described in different area of the city were found to be of the following order.

Residential	ì	ion of Copper	Annual mean
Areas	Min.	Max.	
HIG	0.10	0.062	.02
MIG	0.013	0.066	.039
LIG	0.042	0.079	.03
JJ	0.025	0.062	.067
Industrial	0.027	0.060	.092

The alloy of copper present in material of water pipes is mainly responsible for presence of copper detected in groundwater.

Our studies indicate that level of copper in samples of groundwater collected from different samples is safe for consumption of animals and plants. Indeed, the concentration of copper have been found to be within the same limits in other cities like Nagpur³⁴, Amritsar³⁵ and Patiala³⁶.

3.1.12 Cadmium

Max. permissible limit

0.01 mg/1.

Cadmium may seep through to groundwater from industrial effluents and rivers. Presence of even small amounts of cadmium leads to damage to arteries of human kidney. It is very toxic and is responsible for a number of cases of food poisoning.

However, our studies indicate that no sample of groundwater in any area of Kanpur metro contained any detectable amount of cadmium. Even the samples obtained from different locations with greater susceptibilities to the presence of the metal reported nil cadmium

3.1.13 Chromium

Maximum Permissible limit

 $0.05 \, \text{mg/l}$

The presence of chromium normally present in trivalent and hexavalent forms, in groundwater, may be attributed to the effluents from electroplating plants, paints, dyes explosive and paper industry in which the metal is used in one form or the other. Its intake in drinking groundwater in excess of prescribed limit is carcinogenic to human beings.

In our studies the concentration of chromium the investigated localities were as follows.

Residential	Concentration of Chromium mg/1		Annual mean
Areas	Min.	Max.	
HIG	0.005	0.014	.009
MIG	0.008	0.079	.019
LIG	0.009	0.073	.045
JJ	0.018	0.068	.041
Industrial	0.034	0.122	.049

Although annual mean of in MIG and LIG areas is well below the prescribed maximum limit, there are certain sampling points where the concentration of chromium is above the danger level. Thus is a cause for alarm. Though HIG areas appear to be totally safe from pollution due to chromium, the JJ and IA in the order stated, present a worsying situation. Immediate steps much take to reduc chromium concentration where most of the poor population reside.

3.1.14 Zinc

Max. Permissible limit

= 5.0 mg/l

The pressure of excess zinc in ground water makes it astringent and causes opalescence Indeed, the presence of metal below the maximum permissible limit is desirable and essential for functioning of various enzymes in animals and humans.

In the present investigations, the concentration of zinc in groundwater of different areas may be summarised as follows.

Residential Areas	Concentration of Zinc mg/l		Annual mean
Residential fileas	Min.	Max.	
HIG	2.7	4.2	3.31
MIG	3.08	4.8	3.76
LIG	3.01	4.90	3.97
JJ	2.60	4.92	3.72
Industrial	2.81	4.70	3.79

In all the areas under investigations mean zinc concentration in the ground water is within safe limits. But it is to be noted that the area wise mean maximum in all such localities just below the maximum limit. Naturally, therefore, there are certain sampling points where the zinc concentration exceeds the danger limit. This should be looked into and remedial steps taken.

In fact, similar results have been reported for Nagpur³⁴, and in some part of U.P. by Honda *et al.*³⁸. It is clear that except in some isolated pockets in all areas the zinc concentration in groundwater of Kanpur metro are safe and within the portability standards

3.1.15 Lead

Maximum Permissible limit

= 0.1 mg/l.

Petrol containing tetraethyllead as an anti knock and natural alkylation taken processes produce lead compounds. Lead may also seep through to ground water in dumping areas and industrial areas due to lead accumulators used in automobiles, residences, printing inks and pigments. Beyond the prescribed limits, lead in toxic for human as well as animal consumption.

The investigations reveal the following data for the presence Pb in groundwater of Kanpur.

Residential Areas	Concentration of lead mg/l		Annual mean
	Min.	Max.	,
HIG	0.001	0.016	.008
MIG	0.003	0.010	.006
LIG	0.019	0.073	.058
JJ	0.016	0.08	.042
Industrial	0.014	0.92	.46

One can readily make out from the above data that HIG and MIG people are safe and there contamination of groundwater by lead in these localities is within the safe limits. But some sampling points in LIG and most of them in JJ and IA clusters need our attention as the concentration of lead in the samples concerned is more than the maximum prescribed.

3.1.16 Manganese

Prescribed Max. Limit

= 0.5 mg/l.

As a matter of fact manganese is not a toxic metal. But if it is present in groundwater the taste is affected and if used for laundry, tenacious stains are left behind. It also affects water supply structures. Its origin in groundwater may be traced back to minerals present in earth's crust and domestic waste and industrial effluents which act as pollutants.

The concentration of manganese in various parts of the metro have the determined as under.

Residential Areas		ration of ese mg/l	Annual mean
	Min.	Max.	
HIG	0.010	0.027	.014
MIG	0.010	0.032	.024
LIG	0.060	0.537	.018
JJ	0.076	0.61	.212
Industrial	0.082	0.92	.47

The annual mean values obtained are well within the safe limit. A few samples in LIG, JJ and IA contained larger

concentrations of manganese in the order stated. However, there is no cause of concern.

3.1.17 Nickel

Nickel is among minerals essential for nutrition of living beings. It is comparatively non-toxic. The results obtained for the concentration of the metal different area wise in ground water are as follows.

Residential Areas	Concen	tration of Nickel mg/l	Annual
	Min.	Max.	mean
HIG	0.32	1.22	.912
MIG	0.69	1.31	1.06
LIG	0.92	2.02	1.43
JJ	0.89	4.51	1.67
Industrial	0.86	2.62	1.84

3.2.18 Coliforms

Max. Permissible limit of MPN

= 100/100 ml.

Majority of Indian population depends upon groundwater for drinking purposes. However, pollution of this water which was considered to be the safest has made it unfit for human consumption. The prominent causes of pollution of this source of water are lack of sanitation, improper waste disposal, faults in well construction etc. The outbreak of about 40 epidemics is due to consumption of polluted groundwater contaminated with coliforms.

A number of studies^{25,26,39-45} have been carried out to find bacterial quality of groundwater by determining the extent of presence of haterotrops, choliforms and E. coli.

The presence of choliforms in groundwater in different areas of Kanpur metro were found to be as follows.

Residential Areas	Concent MI Number	-	Annual mean
·	Min.	Max.	
HIG .	101	261	158
MIG	128	740	411
LIG	203	692	432
JJ	210	652	486
Industrial	200	716	397

Not a single sample from LIG, JJ and IA conformed to the prescribed limit. Only a few samples from HIG & MIG had met the standards. It is a serious matter and calls for emergency remedial measures as all types of residential localities specially LIG, JJ and IA areaa.

3.2 Trends and Discussion

When investigating the qualities of ground water from the point of view of potability, it is advisable to have an in-depth look at trends in parameters as they vary seasonally as well as the way they vary from one area to the other and from one sampling station to the other. Such an examination of data can provided us

clues regarding steps to be taken to improve the potability of groundwater.

3.2.1 Seasonal Trends

For the purposes of study of seasonal trends, the samples of water from sampling stations HIG-I; MIG-I, LIG-I, JJ-I and IA-I, were taken into consideration as it was felt than mean values of all five sampling points from the same category of a residential area tend to distort the picture without making an significant and meaningful contribution.

Our analysis has revealed that physicochemical and bacterial parameters as well as heavy metal concentrations exhibit significant alterations among themselves with change in seasons. For all practical purposes, period from July to October was considered the rainy seasons as heavy rainfall occurs due to monsoon during this period. From November to February, it is the winter season when minimum temperature can become as low as 2° centigrade in Kanpur metro. March to June was considered to be the summer season, when mercury some times peaks 49° centigrade during later months.

We have, therefore, found it convenient to divide the year to three so defined seasons and made an attempt study variation of various parameters with respect to change in these climatic conditions. In fact for investigating seasonal trends the sampling stations from each category of residential areas were so chosen that most the parameters, under study, had the most favourable values. Thus we selected the following samples points this purpose.

Identity of the sampling stations.

Residential Areas (RA)

Type of locations	Name of Locations
HIG - I	Residence of Tilak Chauraha, Azad Nagar
MIG - I	Residence of Sri A.B.L. Srivastava, 108/196 Jawahar Nagar, (P. Road)
LIG - I	Residence of Sri Babu Singh, LIG- 2,Dabauli Tern, Ratan Lal Nagar
JJ - I	Residence of Sri Ram Pyare 79B, Railway Gate Sai Purwa (Jhhakarkati) Near Bus Stop
IA - I	Residence of Shushil Pandit, LML Chauraha, Shtyam Shivam Photocopy Centre, Side-3

Tables 3.06 to 3.10 summarise the data so obtained. However, the presentation of data in the tabular form does not make much of sense of it is not analyzed and broken up into seasons.

Therefore, the mean value for all parameters for each of the three seasons for have been summarised in table 3.11 and 3.12.

Table 3.07

Monthly variation in physicochemical parameters, heavy metal concentration and bacteriological characteristics of ground water in MIG-I areas of Kanpur Metro from May 2002 to April 2003.

Voriohle	Unit	May 2002	June	July	August	September	October	November	December,2	January	February	March	April 4003
DH	,	7.90	7.94	7.94	7.98	8.12	8.21	8.51	8.12	8.14	96.7	7.92	7.86
F C	uhos/cm	1306	1338	1346	1358	1576	1827	2076	2444	2206	2308	2006	1505
TDS	mg/1	722	776	817	1004	1186	1184	1093	1052	906	838	856	792
TAIL	mø/!	459	433	546	583	609	633		260	6.04	889	743	772
H T	mg/1	248	256	244	260	271	206	247	256	258	271	274	267
Temn H	mg/]	112	1.1	101	120	129	1.05	112	135	135	140	142	135
Perm.H	mg/l	136 .	145	143	140	142	101	105	121	123	131	132	112
Ca++	mg/1	54	58.4	52.3	58.6	58.9	47.6	48.01	58.4	58.6	58.9	58.3	56
Mg++	mg/l	27.4	26.73	27.5	27.5	30.07	21.14	23.5	26.73	27.09	27.5	31.16	30.8
SO4"	mg/l	90.4	102.6	135.5	163.2	230.6	275.5	211.6	196.4	122.2	126.3	111.6	96.8
[]	mg/l	92.4	100.2	118.3	154.6	193.6	206.4	171.2	135.9	144.8	112.6	100.2	9.96
ix	mg/l	1.42	1.47	1.66	1.71	1.73	1.71	156	1.83	1.92	1.32	1.36	1.41
, ON	mg/l	16.51	17.67	29.22	40.4	39.3	41.6	42.2	36.7	36.4	31.2	26.4	20.3
Fp2+	mg/l	0.064	0.041	0.034	0.032	0.038	0.43	0.68	.078	.061	0.062	0.042	99.0
C112*	mg/1	0.017	6.013	0.012	0.46	0.058	0.084	0.072	0.070	0.072	0.062	0.042	0.019
772+	mg/1	3.21	3.20	3.36	3.52	4.46	5.19	5.02	4.38	4.56	4.30	3.36	3.34
- Coll.	o	0.020	0.015	0.018	0.021	0.024	0.027	0.028	0.021	0.019	0.022	0.016	0.018
5 6	1/sm	0.004	0.0035	0.003	0.0046	0.0069	0.009	0.008	0.0072	900.0	0.0048	0.0040	0.0041
Ma2*	1/sm	0.023	0.017	0.018	0.016	0.021	0.023	0.020	0.082	0.022	0.019	0.028	0.029
Wig:		1.37	1.36	1.32	1.25	0.96	0.92	99.0	0.72	0.81	0.88	0.92	0.98
, in	. /9m	200	070	308	473	509	576	508	517	490	406	356	300/
Coliform	/ IOOM	200	7	3	· :								

Monthly variation in physicochemical parameters, heavy metal concentration and bacteriological characteristics of ground water in LIG-I areas of Kanpur Metro from May 2002 to April 2003. Table 3.08

_				T	Τ	Τ	T	T				Т	T			Τ	Т	Т	T			Т	\top	T	\neg
April 2003	7.04	1460	922	498.4	415	221	194		70	58.3	188.4	147 6	0.11	1.61	19.6	0.066	. 00	.021	4.16	.043	0.046	0.072	1 73	1.73	276
March	7.02	1509	096	4906	406	213	193	261	8.69	56.2	197.6	8 00	0.66	1.56	27.5	0.054		.022	4.31	0.041	0.064	0.086	. 70	1.78	306
February	7.10	1645	1053	514.9	417	221	196	061	73.5	56.6	208.8	106.7	100.7	1.66	33.3	0.063		.026	4.32	0.054	0.082	0.082		1.75	353
January	7.13	1907	1209	553.0	466	242	7 00	t-77	78.5	05.5	214.6	100 6	128.0	1.79	35.9	0.071		.029	4.44	0.068	980.0	0.098		1.76	542
December,2	7.48	2486	1440	682.5	478	050	200	977	79.4	68.18	209.3	11.	157.7	1.81	40.3	0.082	200.0	0.037	4.96	0.075	0.098	0.119	23.5	1.88	631
November	7.96	2476	1678	700.2	506	020	210	236	81.0	73.7	270.5		200.9	1.78	53.6	0.070	0.0.0	0.034	5.11	0.062	0.86	0.530	0.00	1.92	869
October	7.01	2409	1565	763.1	517	020	710	267	83.2	75.0	278.6		203.8	1.88	50.4	0.00	0.73	0.33	5.29	0.052	0.085	0.646	0.040	1.96	692
September	7.92	2206	1486	743.7	518	0.50	208	250	82.9	75.5	256.9		218.6	1.75	49.7		0.074	0.31	5.12	0.036	0.096	0.400	0.438	1.84	586
August	7.53	18.56	1254	708.5	305	200	256	250	81	73.7	214.7	1	173.8	1.62	48.6	2	0.069	0.31	4.27	0.009	0.041	1000	0.335	1.81	415
July	7.22	1388	1176	692.4	65.0	2.50	342	310	100	97.6	1983	2221	14204	1.58	40.0)	990.0	0.25	4.19	0.028	0.032		0.232	1.73	306
June	7.28	1340	1005	657.2	505	coc	271	234	8.0	74.11	176.4	·	106.5	1.51	16.8	10:0	0.052	0.26	4.08	0.031	034		0.071	1.78	243
May 2002	7.30	1353	957	506.3	410	412	213	199	68.9	58.7	180.3	2007	8.68	1.52	6 00	6.27	0.065	.023	4.11	0.04	0.032	200.0	0.068	1.76	224
Ilmit	-	mb/sodin	ma (aum	11/8/11	1/8/11	mg/1	mg/1	mg/l	mø/l		mg/1	mg/1	mg/l	mg/l		mg/1	l/gm	mg/1	mg/1	mg/]	8/	IIIB/1	mg/l	mg/1	100ml
***	Variable	Put Da	2 6	SUL	T.AIK	T.H	Temp.H	Perm.H	++00	, ca	Mg++	S04"	כל	i i	4	NO ₃ .	Fe ² *	C312+	772+	1117	2 3	Pb2:	Mn2+	Ni2+	Coliform

Table 3.09

Monthly variation in physicochemical parameters, heavy metal concentration and bacteriological characteristics of ground water in JJ-I areas of KanpurMetro from May 2002 to April 2003.

7.7 7.82 8.04 1406 1386 1750 957 978 1015 512 528 625 544 627 858 288 346 536 256 286 522 98.8 119 132 72.17 80 128.3 169.6 172.7 221.3 169.6 172.7 221.6 170.3 117.9 261.6 170.3 117.9 261.6 0.23 0.28 0.19 0.036 0.59 0.062 3.3 3.7 3.6 0.018 0.038 0.041 0.009 0.082 0.018 0.018 0.082 0.018 0.038 1.92 2.09 4.59 1.92 2.09 4.59	-11	+	May 2002	June	July	August	September	October	November	December,2	January	February	March	April 2003
1368 1406 1386 1770 2560 2596 2107 1809 1776 1556 909 957 978 1015 1267 1320 1344 12.06 1045 996 994 517 512 528 625 661 717 788 779 743 654 641 283 544 627 858 1225 1388 1523 1297 1044 807 717 289 286 286 286 712 713 768 702 595 7449 807 717 289 286 286 282 522 133 675 755 595 449 306 319 289 286 182 712 713 768 767 755 595 449 307 717 1883 113 1128.3 1181 196.3 2078 7106 188.2 1174 717 <td>5 '</td> <td></td> <td>7.8</td> <td>7.7</td> <td>7.82</td> <td>8.04</td> <td>8.22</td> <td>8.46</td> <td>8.24</td> <td>7.14</td> <td>7.26</td> <td>7.23</td> <td>7.12</td> <td>7.33</td>	5 '		7.8	7.7	7.82	8.04	8.22	8.46	8.24	7.14	7.26	7.23	7.12	7.33
517 512 528 661. 1320 1344 12.06 1045 996 904 517 512 528 625 661. 717 788 796 743 654 641 522 544 627 858 1225 1388 1523 1297 1044 807 717 283 286 536 712 713 768 702 595 501 388 239 256 286 522 513 675 755 595 449 807 717 986 98.8 119 132 192 232 267 29 187.8 1265 319 667.3 72.17 80 128.3 181.0 196.3 207.8 188.2 1195.3 1165.3 117.9 1165.3 117.9 1165.3 118.2 118.2 118.2 118.2 118.2 118.2 118.2 118.2 118.2 118.2 <	nhos	3/cm	1368	1406	1386	1750	177.7	2560	2596	2107	1809	1776	1556	1400
517 512 528 625 661. 717 788 796 743 654 641 522 544 627 858 1225 1388 1523 1297 1044 807 717 283 288 346 536 712 713 768 595 595 501 398 98 98.8 119 132 192 232 267 29 187.8 129.3 126.5 667.3 72.17 80 128.3 181.0 196.3 267.8 29 187.8 129.3 126.5 158.9 166.0 172.7 213.3 279.8 288.7 267.8 29 187.8 126.5 319.6 158.4 176.2 172.7 213.3 279.8 288.7 250.4 210.6 188.7 176.4 97.3 158.4 170.3 117.2 218.6 490.1 581.6 207.8 116.2 116.2 <td< td=""><td>me</td><td>g/1</td><td>606</td><td>957</td><td>826</td><td>1015</td><td>1267</td><td>1320</td><td>1344</td><td>12.06</td><td>1045</td><td>966</td><td>904</td><td>917</td></td<>	me	g/1	606	957	826	1015	1267	1320	1344	12.06	1045	966	904	917
522 544 627 858 1225 1388 1523 1527 1044 807 717 283 288 346 636 712 713 768 702 595 501 398 289 286 286 522 513 675 755 595 449 306 319 98 98.8 119 132 192 232 267 29 187.8 129.3 319 67.3 72.1 80 128.3 181.0 196.3 207.8 188.2 139.6 117.4 97.3 158.9 169.6 172.7 221.3 279.8 288.7 267.4 210.6 187.8 117.4 97.3 158.9 169.6 172.7 221.3 279.8 288.7 260.4 210.6 117.4 176.2 188.1 1160.2 117.4 178.2 158.4 170.2 21.6 428.9 21.6 21.4 1	i å	1/0	517	512	528	625	661.	717	788	962	743	654	641	568
283 288 346 536 712 713 768 702 595 501 398 239 236 286 522 513 675 755 595 449 306 319 98 98.8 119 132 192 232 267 29 187.8 129.3 126.5 67.3 72.17 80 128.3 181.0 196.3 207.8 188.2 139.6 117.4 97.3 158.9 169.6 172.7 221.3 279.8 288.7 260.4 210.6 1887 160.2 117.4 97.3 158.9 169.6 172.7 221.3 279.8 288.7 260.4 210.6 117.4 176.4 176.2 158.9 169.6 172.7 221.3 279.8 288.7 260.4 210.6 117.4 176.3 178.1 158.9 1.67 1.72 21.8 1.96 2.02 2.16 2.16	a de	1/0	522	544	627	858	1225	1388	1523	1297	1044	807	717	617
239 256 286 522 513 675 755 595 449 306 319 98 98 119 132 192 232 267 29 187.8 129.3 126.5 67.3 72.17 80 128.3 181.0 196.3 207.8 188.2 139.6 117.4 97.3 158.9 169.4 172.7 221.3 279.8 288.7 250.4 188.2 139.6 117.4 97.3 158.9 169.6 172.7 221.3 279.8 288.7 250.4 160.6 117.4 177.4 177.7 152.4 170.3 117.9 261.6 490.1 551.6 428.9 317.4 211.6 178.2 158.1 1.67 1.72 1.83 1.88 1.96 2.02 2.14 202 1.92 1.92 27.3 30.6 0.19 0.19 0.18 0.19 0.23 0.21 0.20 0.	am	9/1	283	288	346	536	712	713	768	702	595	501	398	325
98 98.8 119 132 192 232 267 29 187.8 129.3 126.5 67.3 72.17 80 128.3 181.0 196.3 207.8 188.2 139.6 117.4 97.3 158.9 169.6 172.7 221.3 279.8 288.7 250.4 210.6 187. 160.2 187. 97.3 158.9 169.6 172.7 221.3 279.8 288.7 250.4 210.6 188.7 160.2 187. 176.4 177. 188. 1.96 2.02 2.16 428.9 317.4 211.6 176.4 178.2 188.1 188.1 1.96 2.02 2.14 2.14 2.16.6 178.2 178.2 178.2 178.2 178.2 178.2 178.2 178.2 1.62.5 2.02 2.14 2.02 1.92.3 34.4 178.2 1.62.3 0.21 0.21 0.03 0.03 0.04 0.03 0.04 0.05 0.05 <td>i i</td> <td>9/1</td> <td>239</td> <td>256</td> <td>286</td> <td>522</td> <td>513</td> <td>675</td> <td>755</td> <td>595</td> <td>. 449</td> <td>306</td> <td>319</td> <td>325</td>	i i	9/1	239	256	286	522	513	675	755	595	. 449	306	319	325
67.3 72.17 80 128.3 181.0 196.3 207.8 188.2 139.6 117.4 97.3 158.9 169.6 172.7 221.3 279.8 288.7 250.4 210.6 1887 160.2 158.1 152.4 170.3 117.9 261.6 490.1 551.6 428.9 317.4 211.6 176.4 178.2 1.57.4 170.3 117.9 261.6 490.1 551.6 428.9 317.4 211.6 176.4 178.2 1.57.4 1.70.3 1.17.9 261.6 490.1 551.6 2.02 2.14 2.02 1.96.3 1.63.7 27.3 3.0.6 43.7 53.6 54.9 58.3 60.2 61.4 58.6 52.3 34.4 0.028 0.036 0.061 0.019 0.061 0.063 0.061 0.061 0.064 0.064 0.064 0.064 0.064 0.064 0.064 0.064 0.064 0.064		g/1	86	98.8	119	132	192	232	267	29	187.8	129.3	126.5	115.4
158.9 169.6 172.7 221.3 279.8 288.7 250.4 210.6 1887 160.2 158.1 152.4 170.3 117.9 261.6 490.1 551.6 428.9 317.4 211.6 176.4 178.2 1.67 1.79 161.6 490.1 551.6 428.9 317.4 211.6 176.4 178.2 1.67 1.72 1.83 1.88 1.96 2.02 2.16 1.94 1.63 1.63 27.3 30.6 43.7 53.6 54.9 58.3 60.2 61.4 58.6 52.3 34.4 0.19 0.28 0.19 0.19 0.19 0.19 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 <td></td> <td>8/1</td> <td>67.3</td> <td>72.17</td> <td>80</td> <td>128.3</td> <td>181.0</td> <td>196.3</td> <td>207.8</td> <td>188.2</td> <td>139.6</td> <td>117.4</td> <td>97.3</td> <td>79.8</td>		8/1	67.3	72.17	80	128.3	181.0	196.3	207.8	188.2	139.6	117.4	97.3	79.8
152.4 170.3 117.9 261.6 490.1 551.6 428.9 317.4 211.6 176.4 178.2 1.67 1.72 1.83 1.88 1.96 2.02 2.16 2.14 2.02 1.92 1.63 27.3 30.6 43.7 53.6 54.9 58.3 60.2 61.4 58.6 52.3 34.4 0.19 0.23 0.26 61.4 58.6 52.3 34.4 1.63 0.028 0.036 0.049 0.049 0.049 0.049 0.061 0.061 0.058 0.020 0.21 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.064 0.065 0.066 0.066 0.066 0.066 0.066 0.066 0.064 0.041 0.041 0.041 0.041 0.041 0.041 0.041 0.041 0.041 0.041 0.041 0.041 0.041 0.041 0.042 0.041 0.042 0.041 <td>m</td> <td>1/20</td> <td>158.9</td> <td>169.6</td> <td>172.7</td> <td>221.3</td> <td>279.8</td> <td>288.7</td> <td>250.4</td> <td>210.6</td> <td>1887</td> <td>160.2</td> <td>158.1</td> <td>162.3</td>	m	1/20	158.9	169.6	172.7	221.3	279.8	288.7	250.4	210.6	1887	160.2	158.1	162.3
1.67 1.72 1.88 1.96 2.02 2.16 2.14 2.02 1.92 1.63 27.3 30.6 43.7 53.6 54.9 58.3 60.2 61.4 58.6 52.3 34.4 0.19 0.23 6.28 0.19 0.19 0.18 0.19 0.23 0.20 0.21 0.19 0.028 0.036 0.59 0.062 0.061 0.061 0.061 0.061 0.058 0.033 0.030 2.9 3.3 3.7 3.6 4.4 4.84 4.92 4.88 4.29 3.88 3.02 0.037 0.038 0.041 0.039 0.035 0.068 0.066 0.066 0.062 0.041 0.012 0.018 0.028 0.039 0.039 0.091 0.091 0.092 0.81 0.042 0.044 0.048 0.079 0.082 0.038 0.051 0.069 0.071 0.053 0.044 0.048 <td>m</td> <td>g/1</td> <td>152.4</td> <td>170.3</td> <td>117.9</td> <td>261.6</td> <td>490.1</td> <td>551.6</td> <td>428.9</td> <td>317.4</td> <td>211.6</td> <td>176.4</td> <td>178.2</td> <td>163.0</td>	m	g/1	152.4	170.3	117.9	261.6	490.1	551.6	428.9	317.4	211.6	176.4	178.2	163.0
27.3 30.6 43.7 53.6 54.9 58.3 60.2 61.4 58.6 52.3 34.4 0.19 0.20 0.23 0.20 0.19 0.18 0.19 0.19 0.19 0.19 0.19 0.19 0.19 0.19 0.19 0.19 0.19 0.01 0.020 0.020 0.020 0.03 0.03 0.03 0.03 0.03 0.061 0.061 0.061 0.03 0.03 0.03 0.061 0.062 0.03 0.03 0.03 0.066 0.066 0.041 0.041 0.03 0.03 0.068 0.066 0.066 0.041 0.041 0.044 0.048 0.066 0.066 0.044 0.048 0.069 0.066 0.066 0.044 0.048 0.044 0.048 0.044 0.048 0.044 0.048 0.044 0.048 0.044 0.048 0.044 0.048 0.044 0.048 0.044 0.048 0.044 0.044 0.048 <td< td=""><td>m</td><td>g/l</td><td>1.67</td><td>1.72</td><td>1.83</td><td>1.88</td><td>1.96</td><td>2.02</td><td>2.16</td><td>2.14</td><td>2.02</td><td>1.92</td><td>1.63</td><td>1.47</td></td<>	m	g/l	1.67	1.72	1.83	1.88	1.96	2.02	2.16	2.14	2.02	1.92	1.63	1.47
0.19 0.23 0.28 0.19 0.18 0.19 0.19 0.23 0.23 0.23 0.19 <th< td=""><td>J. J.</td><td>1/6</td><td>27.3</td><td>30.6</td><td>43.7</td><td>53.6</td><td>54.9</td><td>58.3</td><td>60.2</td><td>61.4</td><td>58.6</td><td>52.3</td><td>34.4</td><td>32.1</td></th<>	J. J.	1/6	27.3	30.6	43.7	53.6	54.9	58.3	60.2	61.4	58.6	52.3	34.4	32.1
0.028 0.036 0.059 0.061 0.061 0.061 0.058 0.032 0.030 0.030 2.9 3.3 3.7 3.6 4.4 4.84 4.92 4.88 4.29 3.88 3.02 0.037 0.038 0.041 0.039 0.036 0.068 0.066 0.066 0.066 0.067 0.041 0.012 0.018 0.02 0.08 0.051 0.091 0.052 0.01 0.074 0.038 0.0779 0.082 0.038 0.051 0.069 0.071 0.053 0.044 0.048 1.81 1.92 2.09 4.59 2.06 1.98 1.36 1.24 1.09 1.08 1.11 257 324 351 478 507 706 698 606 452 333 306		. /9	0.19	0.23	0.28	0.19	0.19	0.18	0.19	0.23	0.20	0.21	0.19	0.18
2.9 3.3 3.7 3.6 4.4 4.84 4.92 4.88 4.29 3.88 3.02 0.037 0.038 0.041 0.039 0.036 0.056 0.066 0.066 0.065 0.041 0.038 0.012 0.018 0.021 0.051 0.069 0.071 0.053 0.074 0.038 0.079 0.082 0.038 0.051 0.069 0.071 0.053 0.044 0.048 1.81 1.92 2.09 4.59 2.06 1.98 1.36 1.24 1.09 1.08 1.11 257 324 351 478 507 706 698 606 452 333 306		1/9	0.028	0.036	0.59	0.062	0.061	0.063	0.061	0.061	0.058	0.032	0.030	0.028
0.037 0.038 0.041 0.039 0.036 0.056 0.066 0.066 0.065 0.0674 0.038 0.012 0.018 0.02 0.018 0.05 0.08 0.091 0.92 0.81 0.074 0.038 0.079 0.082 0.018 0.051 0.069 0.071 0.053 0.044 0.048 1.81 1.92 2.09 4.59 2.06 1.98 1.36 1.24 1.09 1.08 1.11 257 324 351 478 507 706 698 606 452 333 306		5/1	9.6	3.3	3.7	3.6	4.4	4.84	4.92	4.88	4.29	3.88	3.02	3.00
0.012 0.018 0.02 0.018 0.05 0.08 0.091 0.092 0.81 0.074 0.038 0.012 0.018 0.02 0.018 0.051 0.069 0.071 0.053 0.044 0.048 0.079 0.082 0.092 0.071 0.053 0.074 0.048 0.048 1.81 1.92 2.09 4.59 2.06 1.98 1.36 1.09 1.08 1.11 257 324 351 478 507 706 698 606 452 333 306	ii	1/8/1	2:50	0.038	0.041	0000	0.039	0.056	0.068	0.066	990.0	0.062	0.041	0.039
0.012 0.018 0.019 0.019 0.051 0.059 0.071 0.053 0.053 0.044 0.048 1.81 1.92 2.09 4.59 2.06 1.98 1.36 1.24 1.09 1.08 1.11 257 324 351 478 507 706 698 606 452 333 306	ĩ	8/1	0.037	0.000	1.00	0.018	0.05	0.08	0.091	0.92	0.81	0.074	0.038	0.021
0.079 0.082 .0192 0.038 0.051 0.069 0.071 0.053 0.071 0.053 0.071 0.073 0.071 0.073 0.071 <th< td=""><td>ш</td><td>8/1</td><td>0.012</td><td>0.018</td><td>0.02</td><td>0.010</td><td>66.6</td><td>20:0</td><td>1000</td><td>0.059</td><td>030</td><td>0.044</td><td>0.048</td><td>0.062</td></th<>	ш	8/1	0.012	0.018	0.02	0.010	66.6	20:0	1000	0.059	030	0.044	0.048	0.062
1.81 1.92 2.09 4.59 2.06 1.98 1.36 1.24 1.09 1.08 1.11 257 324 351 478 507 706 698 606 452 333 306	Ĕ	g/1	0.079	0.082	.0192	0.038	0.051	0.069	0.071	0.053	760	4.0.4	250.0	1.30
257 324 351 478 507 706 698 606 452 333 306	ĬĬ.	8/1	1.81	1.92	2.09	4.59	2.06	1.98	1.36	1.24	1.09	1.08	1.11	1.39
	100	0ml	257	324	351	478	507	902	869	909	452	333	306	278

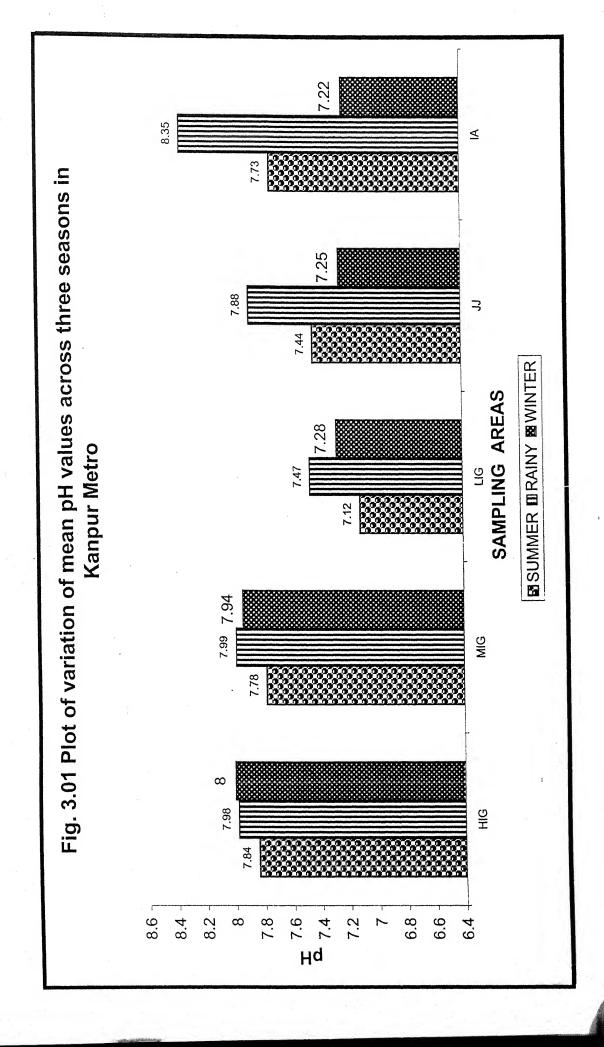
Monthly variation in physicochemical parameters, heavy metal concentration and bacteriological characteristics of ground water in IA-I areas of Kanpur Metro from May 2002 to April 2003. **Table 3.10**

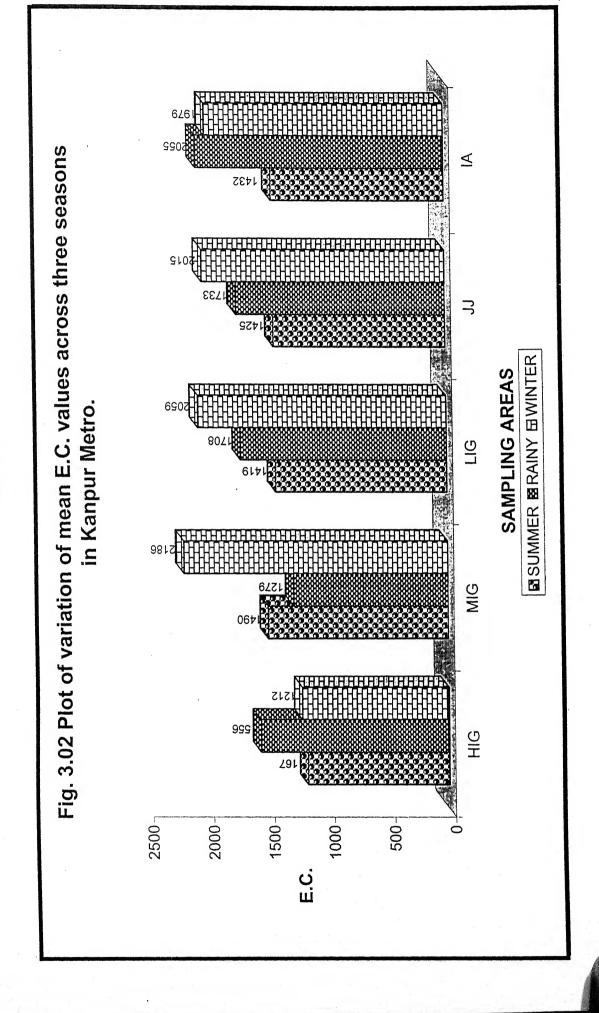
				_	_																				
April 2000	7.84	1545	868	496.6	616	220	332	284	102.8	87.2	135 9		132.8	1.67	27.6		.17	0.048	3.62	0.041	0.024	.88		2.00	253
матсп	7.82	1660	906	521.9	696	000	905	327	113.4	100.2	140 4		142.6	1.78	33.4		.16	0.052	4.06	0.43	0.031	11.	9	7.07	255
repruary	7.74	1754	965	554.2	1153	2011	286	567	187.4	166.3	146.9	7.0.7	180.8	1.82	41.9		.19	0.061	4.62	0.059	0.052	.21		2.61	255
January	7.86	1840	1110	688.4	1961	1621	631	620	227.1	166	102 6	103.0	366.7	1.82	47.3	0.77	.22	0.071	4.78	0.072	920.	44.		2.87	263
December,2	7.91	2197	1240	715.2	2001	1230	642	594	222.3	165.3	7 001	198.4	306.9	1.93	0.07	7.64	.24	0.069	5.02	0.66	.088	56	2	3.31	388
November	8.20	2496	1255	665.4		1496	7571	739	314.6	142.4		234.7	368.4	2.01	11.1	4(.,	.19	0.063	5.11	0.068	.092	09	60.	3.38	556
October	8.54	2506	1360	590.4	1.000	1283	029	613	237.9	167.0	7.101	265.3	275.2	1.96		46.6	.18	0.063	34.81	0.056	0.076	7.9	,o.	4.01	999
September	8.32	1490	1452	5 1 2	231.2	1148	586	562	187.5	165.0	100.9	260.5	412.5	195		41.9	.11	0.059	3.43	0.037	0.054	04	.42	3.83	8.60
August	7.88	1475	1160	1601	403.1	968	456	440	145	100 6	129.0	196.4	267.3	1.73		50.1	60.	0.058	3.34	0.026	0.022	00	38.	3.63	567
July	7.90	1370	1119	0.07	421.2	630	332	298	66		92.9	174.8	215.6	1.73		40.6	.19	0.653	3.28	0.032	0.021		.194	2.24	371
June	7.78	1390	1017	1101	4/0.6	517	273	244	81.4		76.1	172.2	156.7	1.68	1.00	23.9	.18	0.049	3.22	.039	0.019		.084	2.03	290
May 2002	7.81	1378	688	200	492.5	502	260	242	80		73.3	150.4	112.4	1 60	1.02	234	.15	.046	3.11	0.038	0.015	010.0	.082	1.91	251
Unit		iihos/cm	17	mg/1	mg/l	mg/l	mg/l	mg/l	1/200	11/SIII	mg/l	mg/1	mg/l	5	mg/1	mg/l	mø/l	- /s	e/.	S/ .	111g/1	mg/1	mg/1	mg/l	/100ml
Voriohle	Hu	P. C.		TDS	T.Alk	T.H	Temp.H	Perm H		Ca++	Mg++	S04	į	3	ČŁ,	NO	F.02+	2.7	- La -	-117	ב ל	Pb24	Mn2+	Ni2+	Coliform

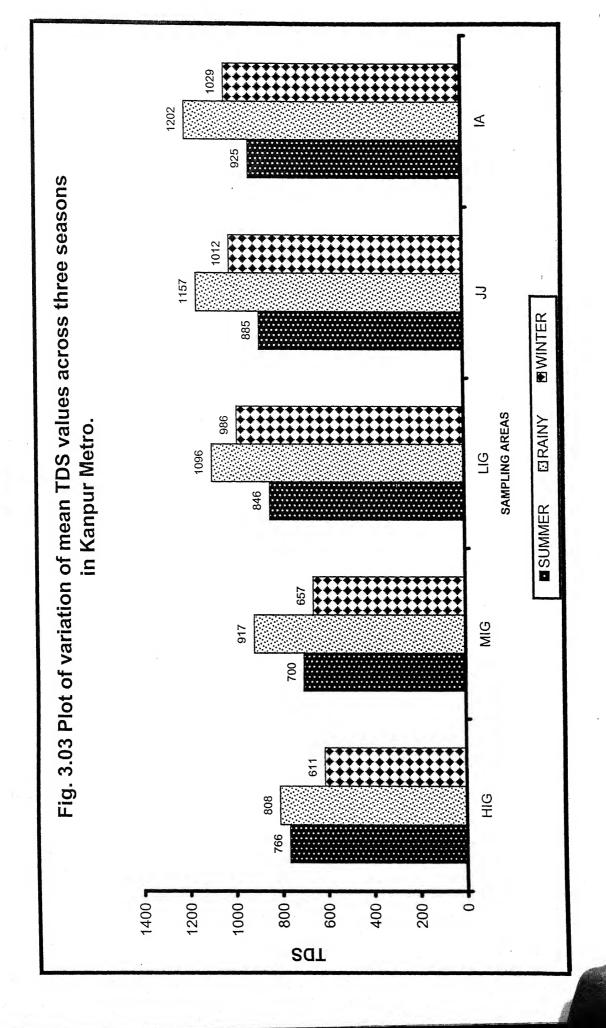
Figures 3.01 to 3.20 depict the seasonal variation of the various characteristics of ground water.

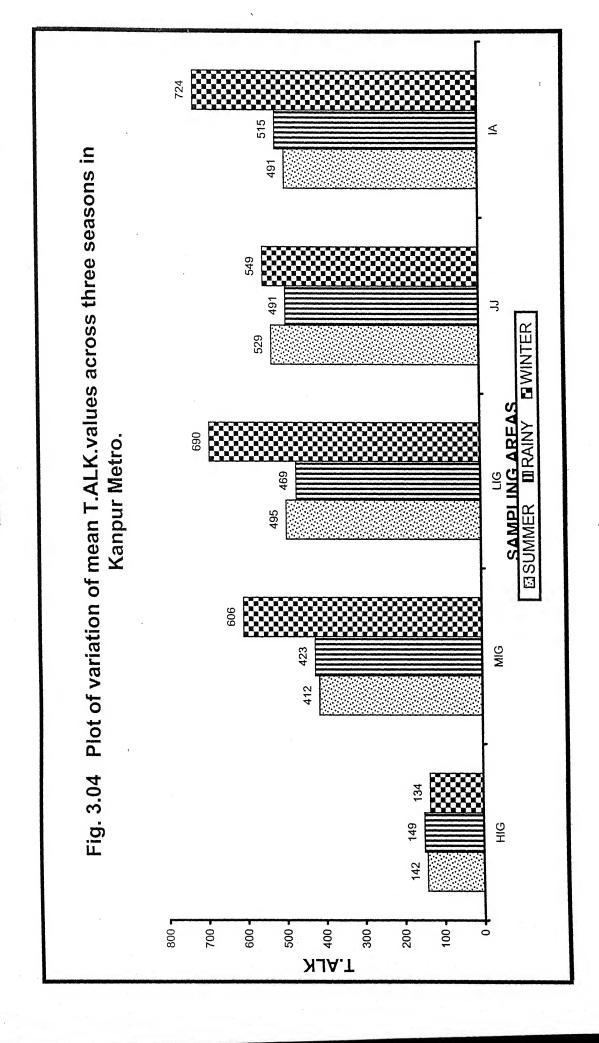
The data provided in the table and figures make it amply clear that much variation is observed during October to April Most parameters decrease during summer and increase during the raining season and then begin to decrease again in winter followed by summer.

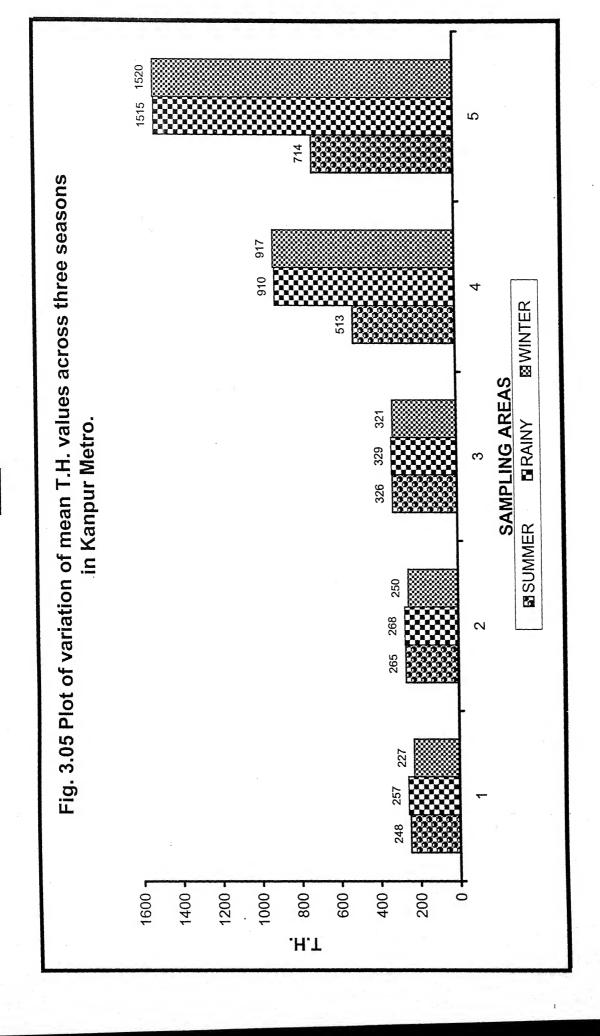
It is postulated that during the raining season, these is general increase in cationic and anionic species which slowly seep through the ground to pollute the water. On the onset of monsoon in later half of June, the contaminants present in the atmosphere get dissolved and are brought down to the earth. In addition, during recharge of groundwater during the raining season, greater amounts of pollutants from factories waste dumps etc. are able to reach the bottom to mix with groundwater It is also observed that in some cases this seepage is delayed due to local ground conditions and nature of discharge so that peak value of the pollutants are observed during the winter season. A Kaur⁴⁶ et al. has studied obtained similar results for water obtained from shallow aquifers in Rajpura. In fact, this is the trend in most cases.

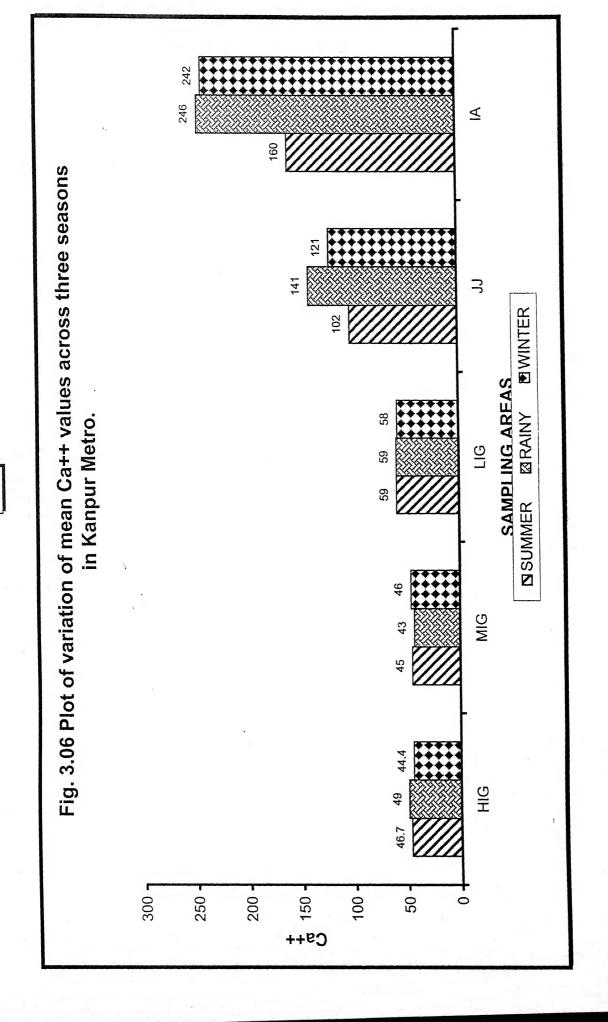


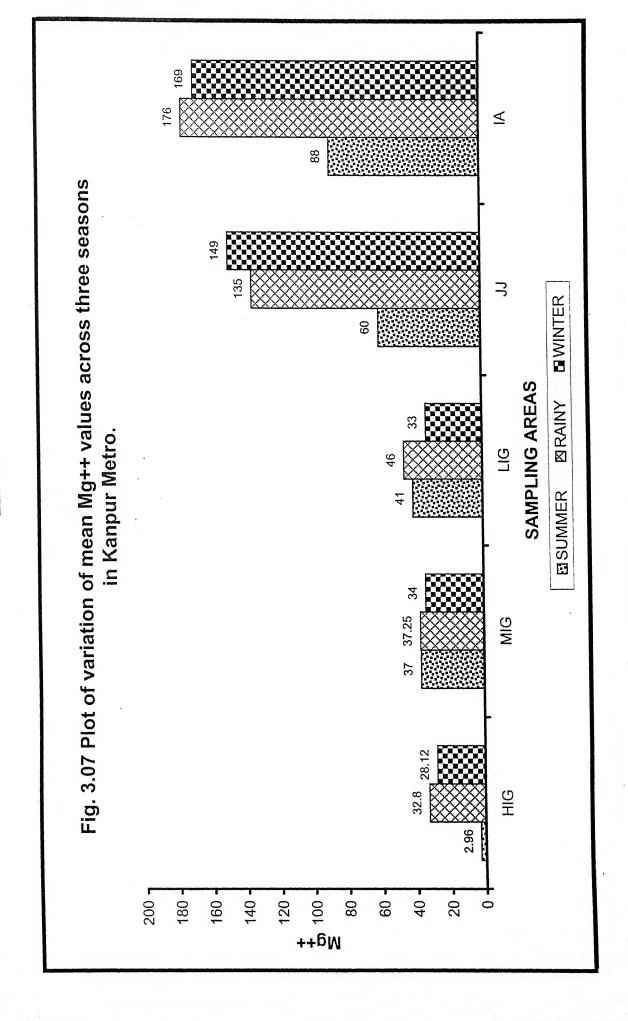


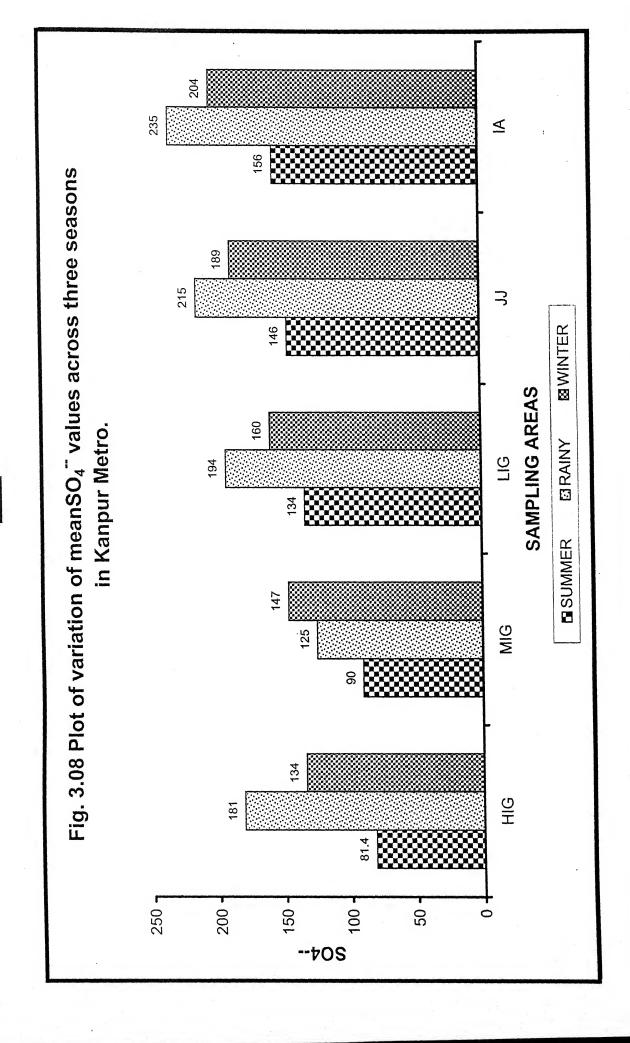


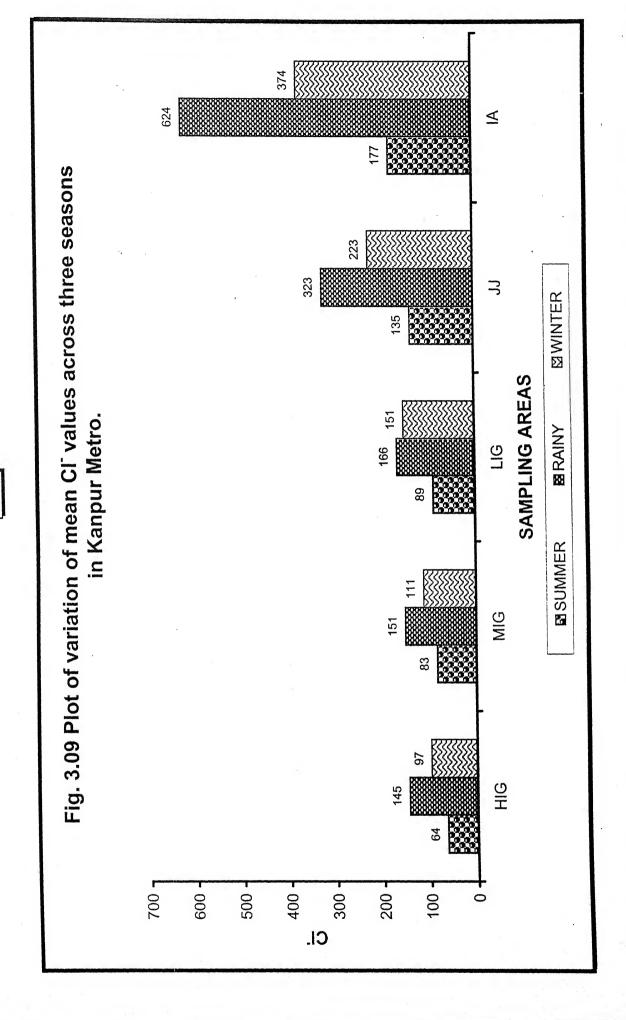


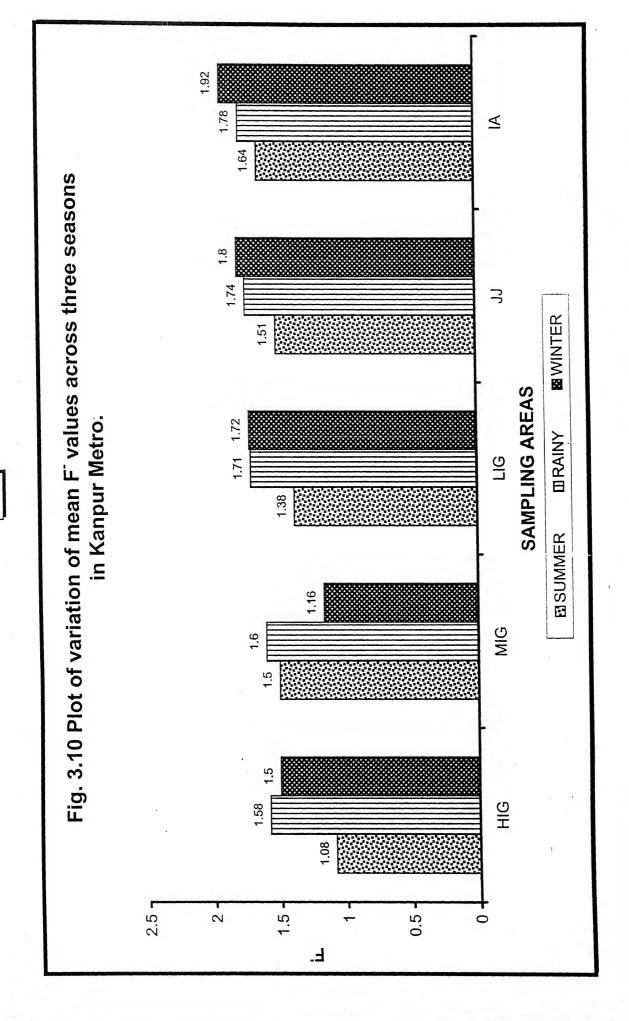


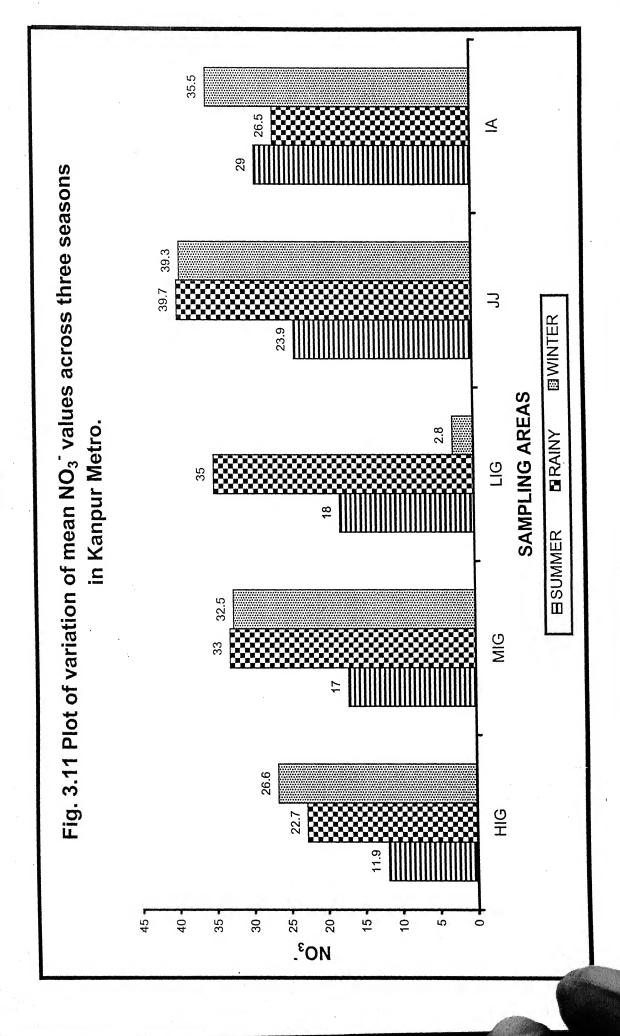


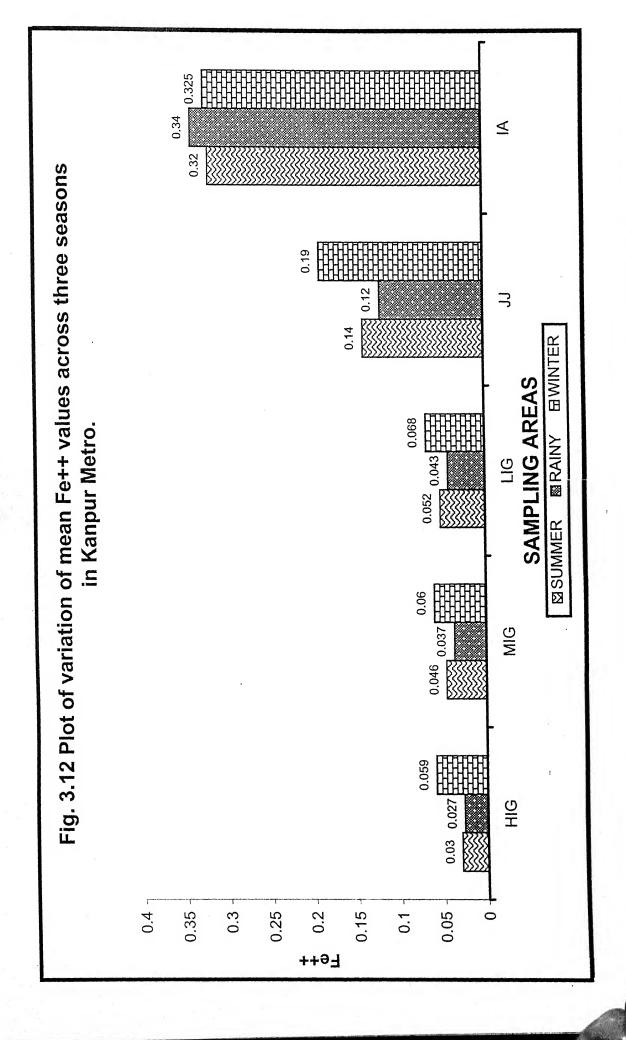


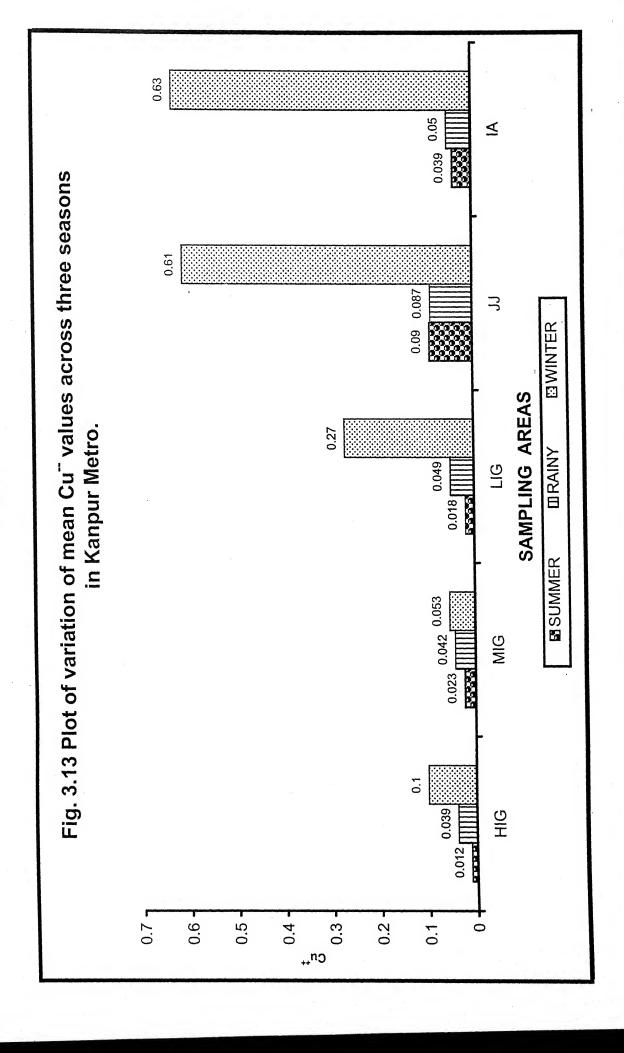


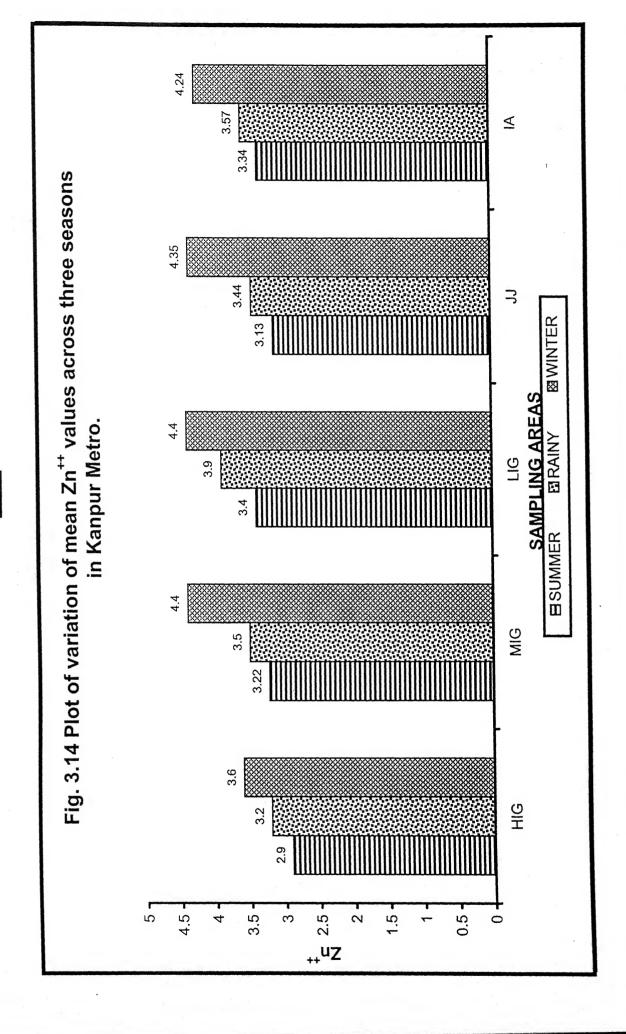


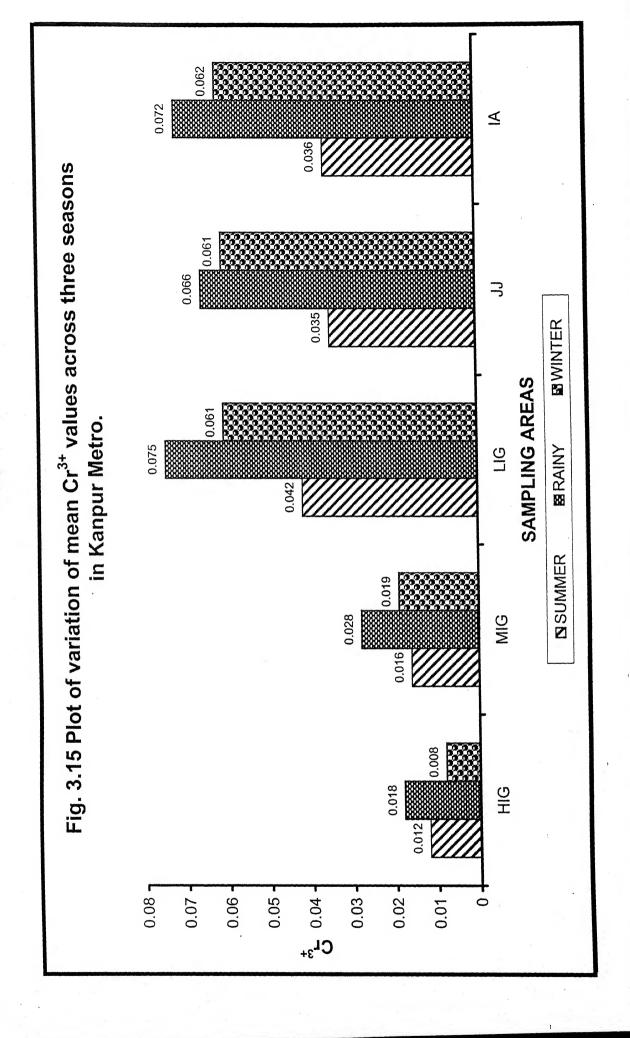


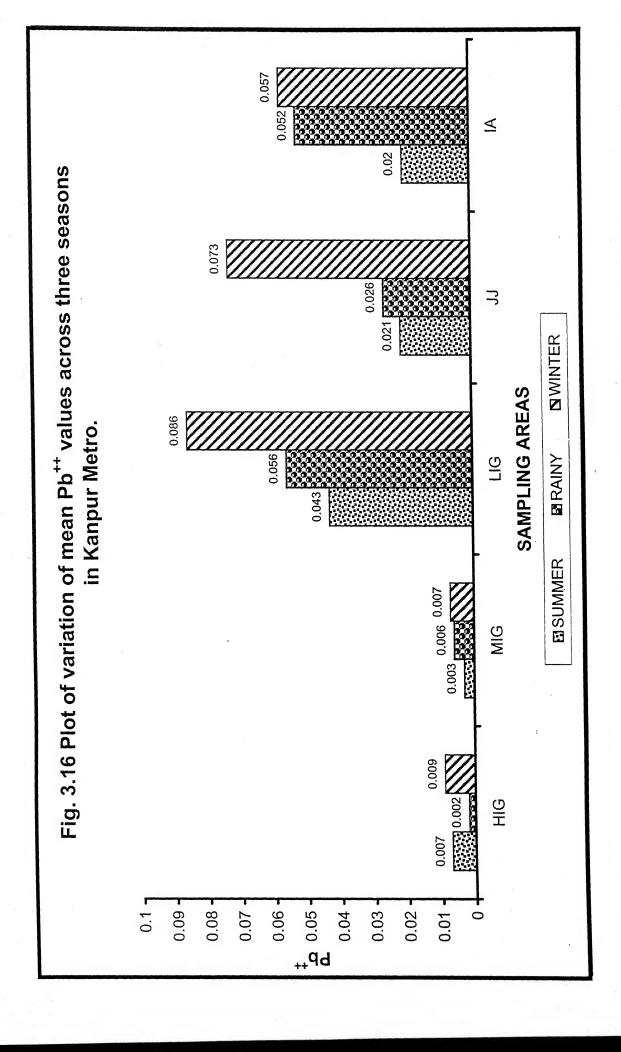


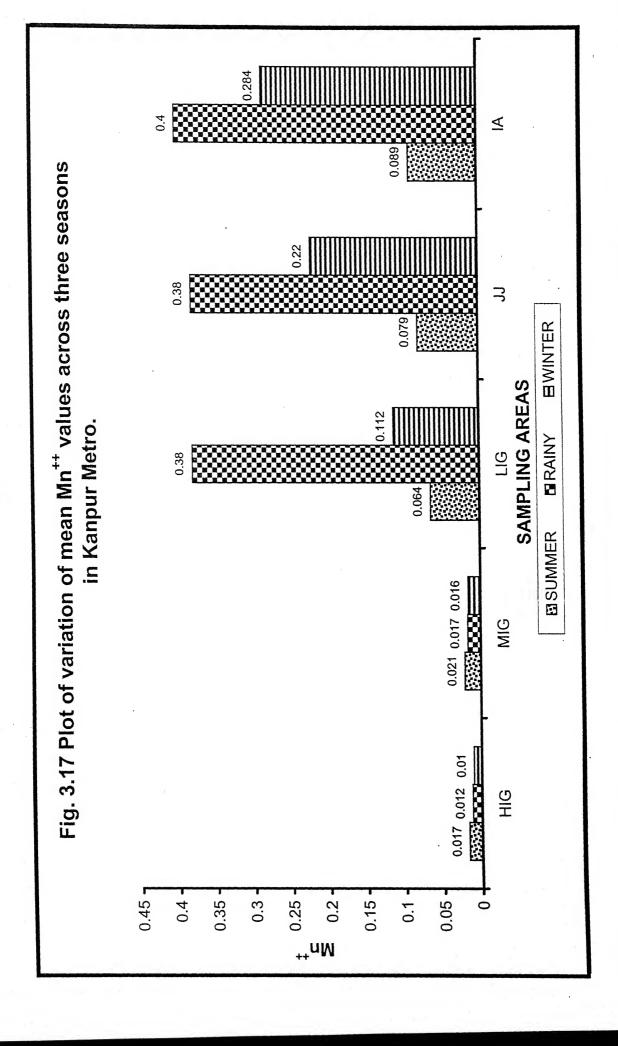


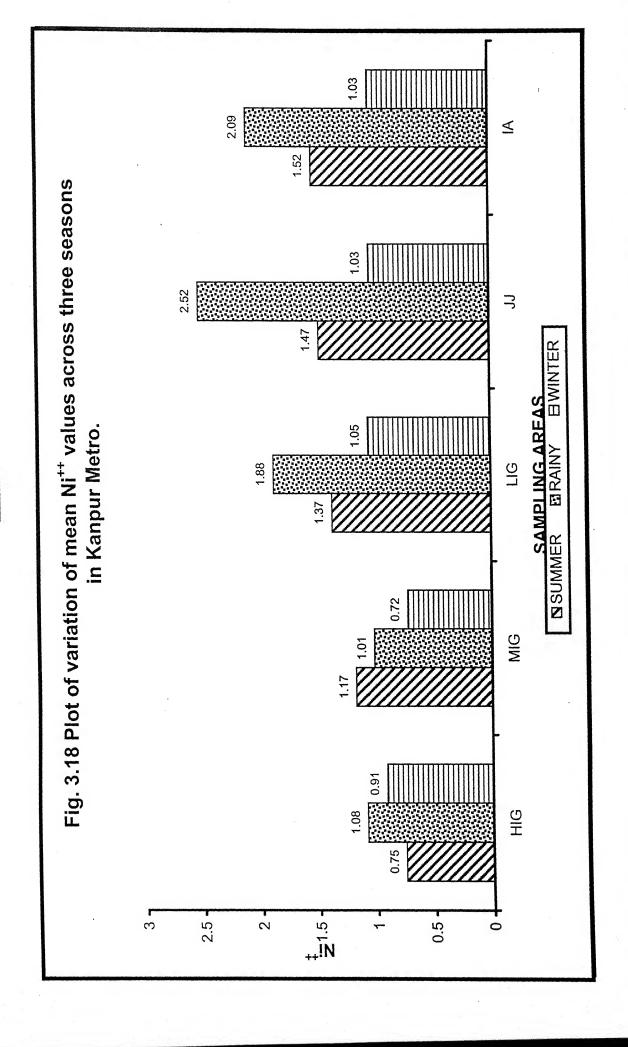


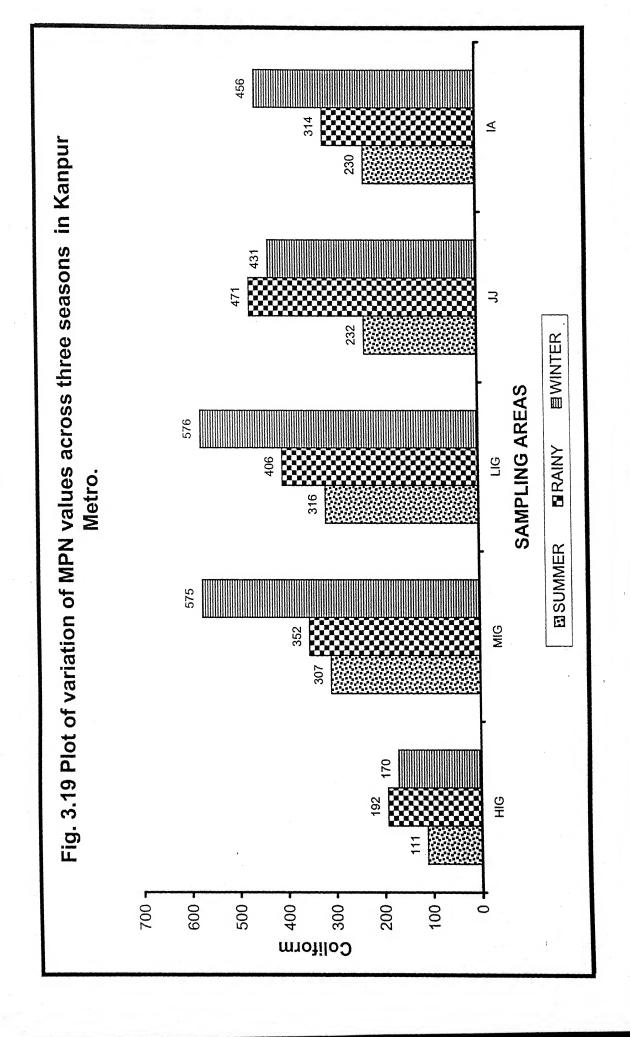


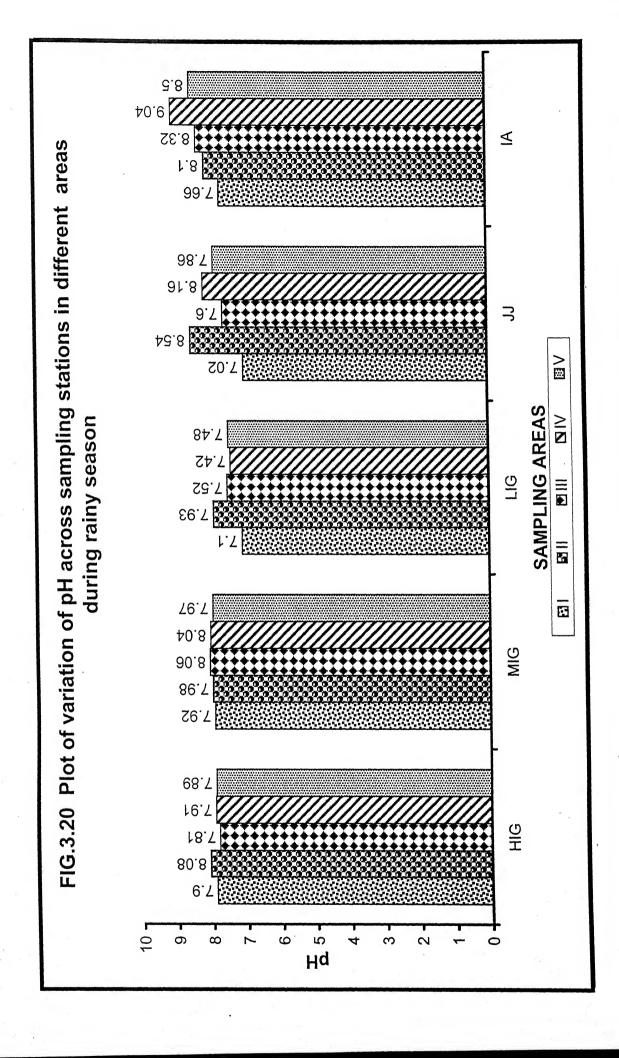












3.2.2 Sub-area wise trends and discussion

As already stated earlier, we have taken samples from five points in each class of residential area. It would be useful to analyze the trends of physicochemical parameter, concentrations of heavy metals in terms of sampling stationwise results of the groundwater sample obtained to gain an insight into the type of factors that contributes towards pollution of groundwater. It has been noticed that the rainy season is the best time, for sampling station wise comparison for at that time, as we have already observed, the groundwater pollution is at its worst for most of the pollutants. For purposes of study of variation of sub-area trends, therefore, the mean values for the months of rainy season were considered for each sampling station.

(a) High Income Group Sampling Station:

Table 3.13 and 3.14 contains the data on variation of the various physicochemical heavy metals across sampling stations during the raining season (July to Oct. 2002) and the same is graphically depicted in Fig. 3.20 and fig. 3.38 for clarity and easier to understand format.

A perusal of the data presented in these tables and figures leads us to the definite conclusion that groundwater from HIG-I-sampling station at Tilak Chauraha, Azad Nagar, is least contaminated while the one at HIG-IV (Near Rama Hospital Lakhanpur) the most contaminated in terms of most physicochemical parameters and heavy metals concentration. Even then there is little cause for concern as the contaminants

concentration is well within tolerable limits and HIG-I ground water appears to be best groundwater available in Kanpur metro. The reason for maximum pollution of groundwater at HIG-IV is not far to seek. Among the five sampling station HIG IV located in Lakhanpur is surrounded by wastage dumps and some farther away are small industries in Panki. Similar factors, to a less extent pollute the groundwater at other sampling stations.

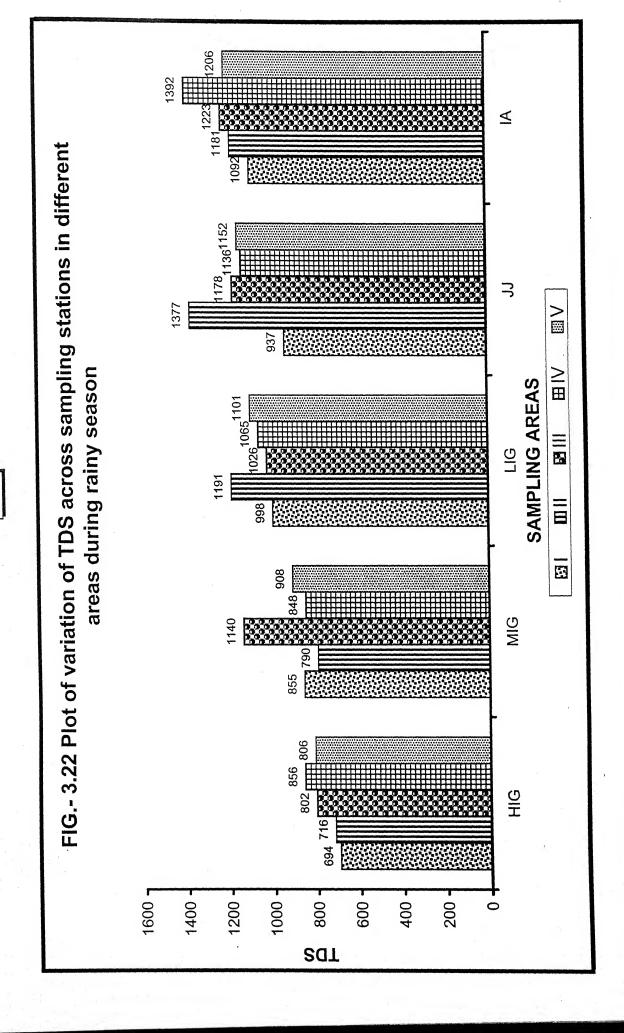
(b) Middle Income Group Sampling Stations:

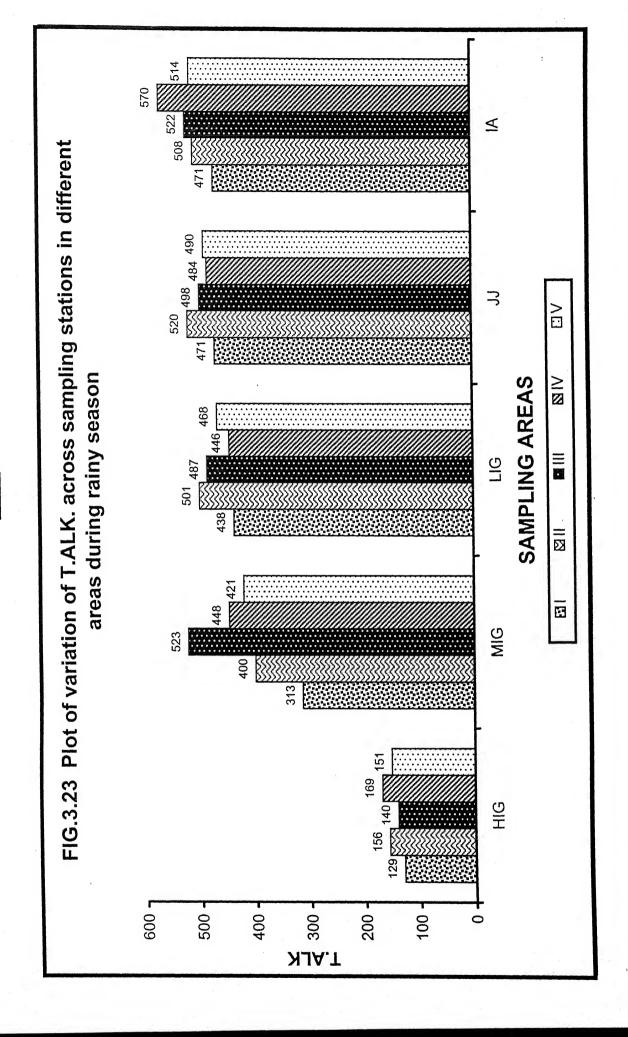
The data on variation in physicochemical parameters and heavy metal concentration across sampling stations in rainy season is present in table 3.15 and 3.16 and figures 3.21 and 3.39.

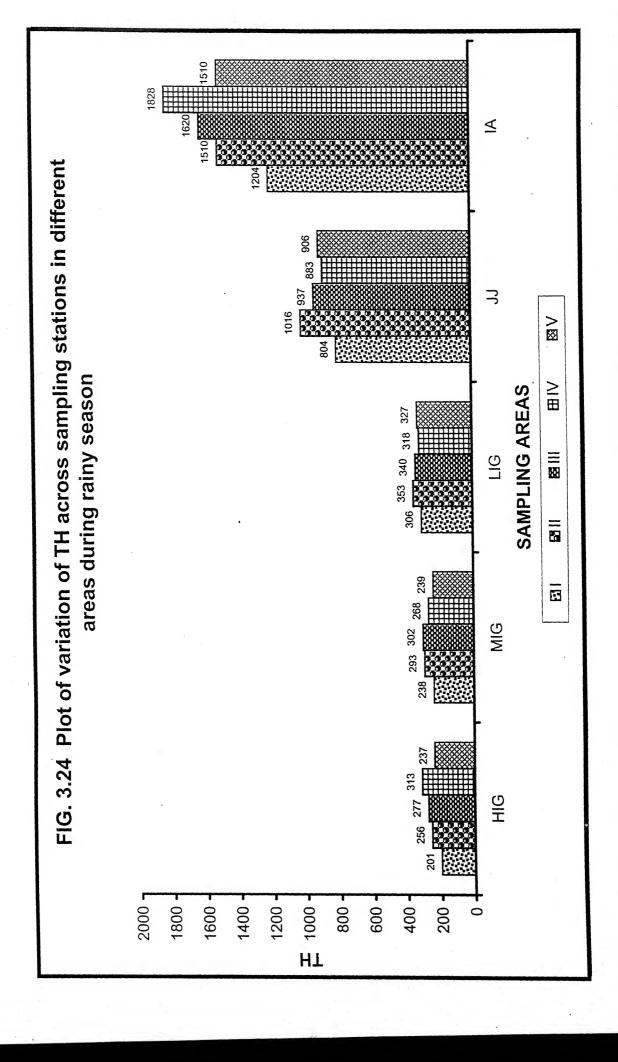
It is obvious from the data that MIG III sampling station i.e. the one situated in Durga Mandir, Govind Nagar has the worst groundwater among the samples obtained from MIG residential areas. It is probably because this MIG locality as a whole has in colonies and industrial area of Dada Nagar in the neighbourhood.

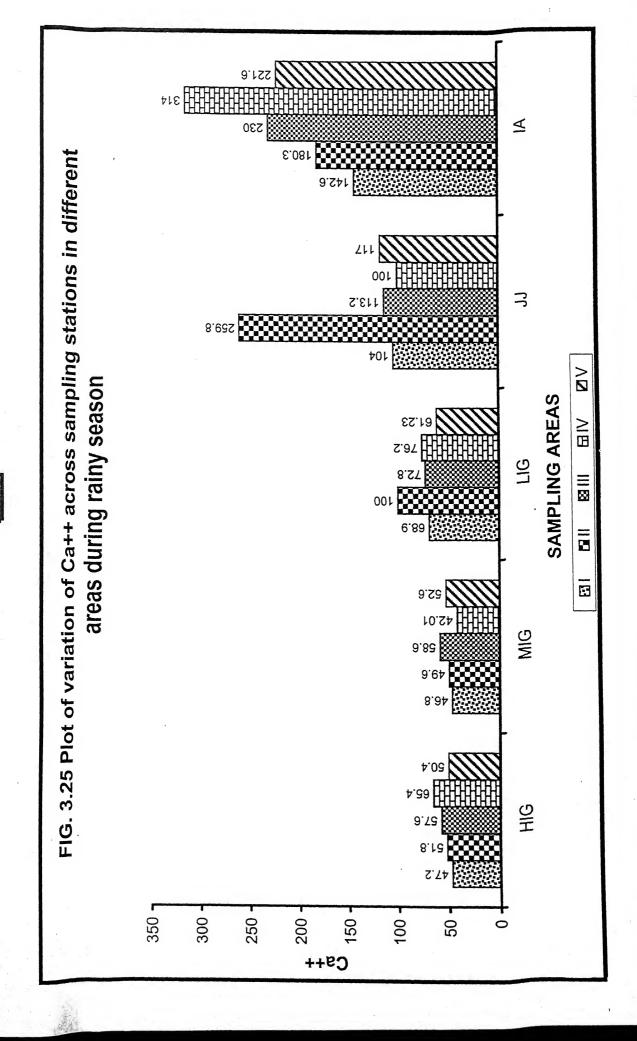
Among the MIG sampling stations, MIG-I i.e. Jawahar Nagar on P. Road, has the best potability, as far as its groundwater is concerned. The surrounding locality is devoid of any waste dump, factory area and any other polluting source. The other sampling stations have some source of pollution in their vicinity. For example MIG-II in Kidwai Nagar has vegetable mandi in the vicinity while MIG IV and V are situated respectively in Saket Nagar and Kakadeo have a Nullas and local waste dumps in the neighbourhood.

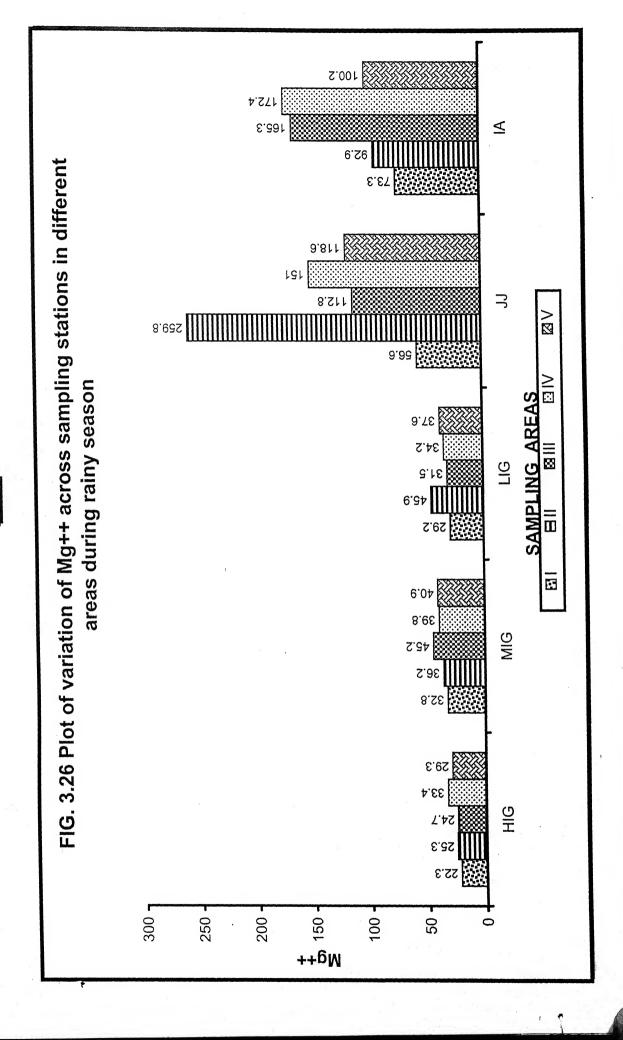
Fig. 3.21 Plot of variation of E.C. across sampling sations in different areas during 2663 ≤ 848 9961 Sampling Areas rainy season 1590 8761 1210 읟 7000€ 2000-500- 2500 1000 E.C. 1500-

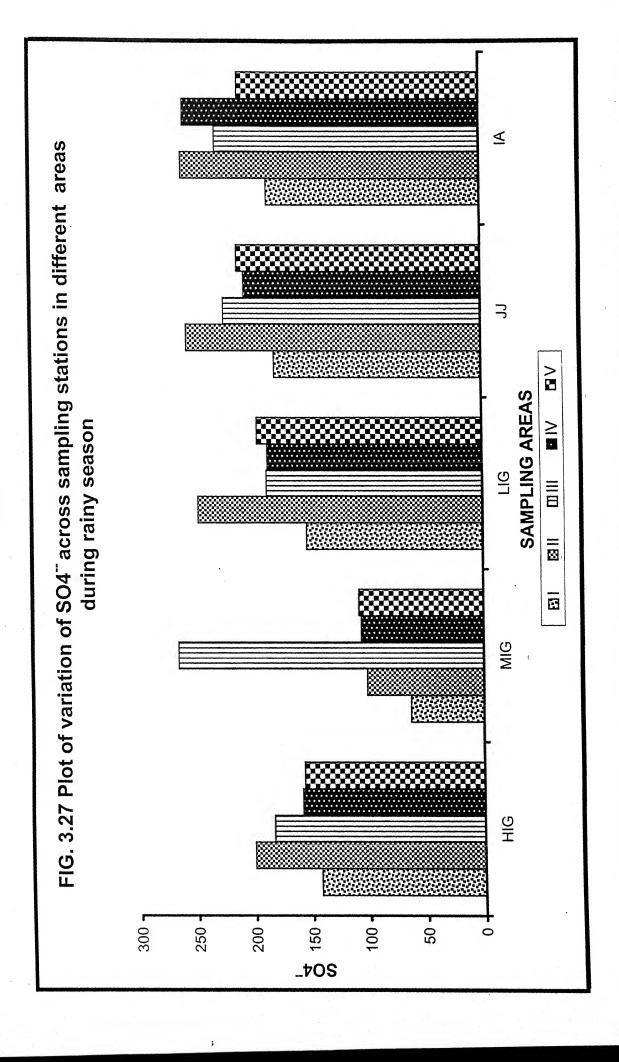


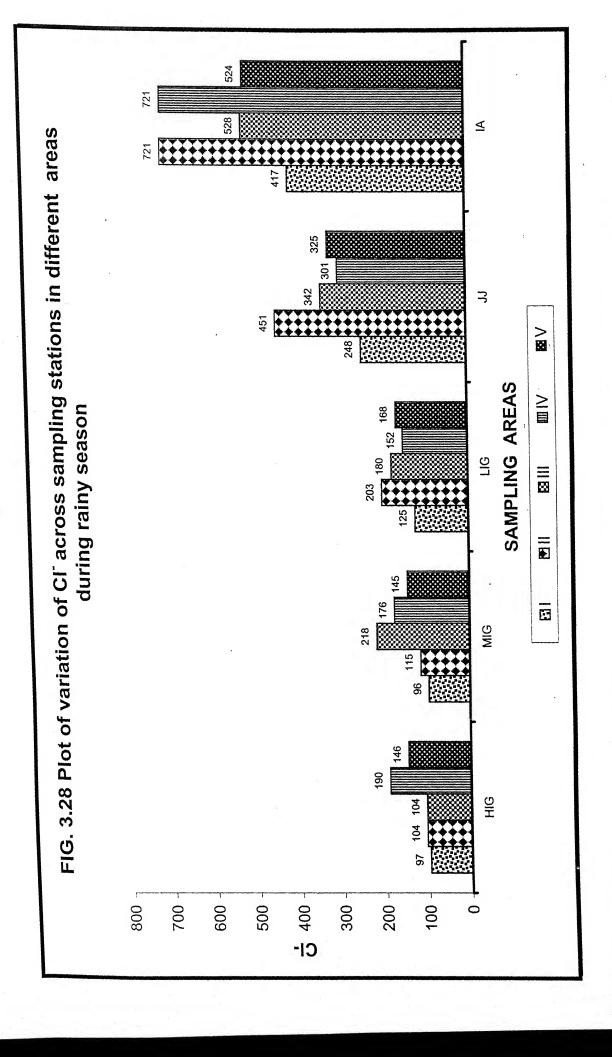


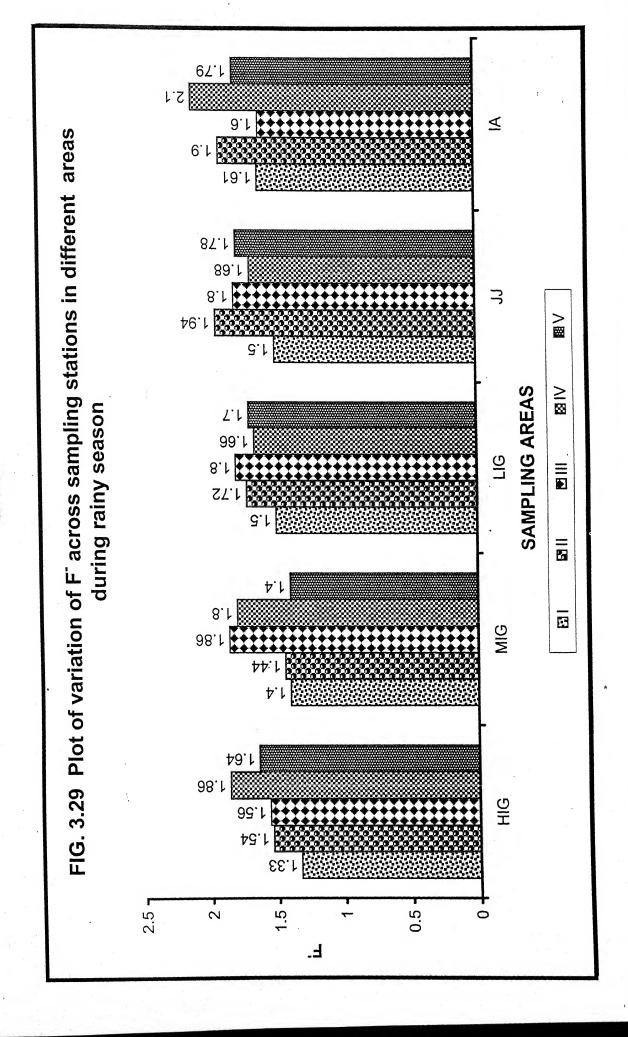


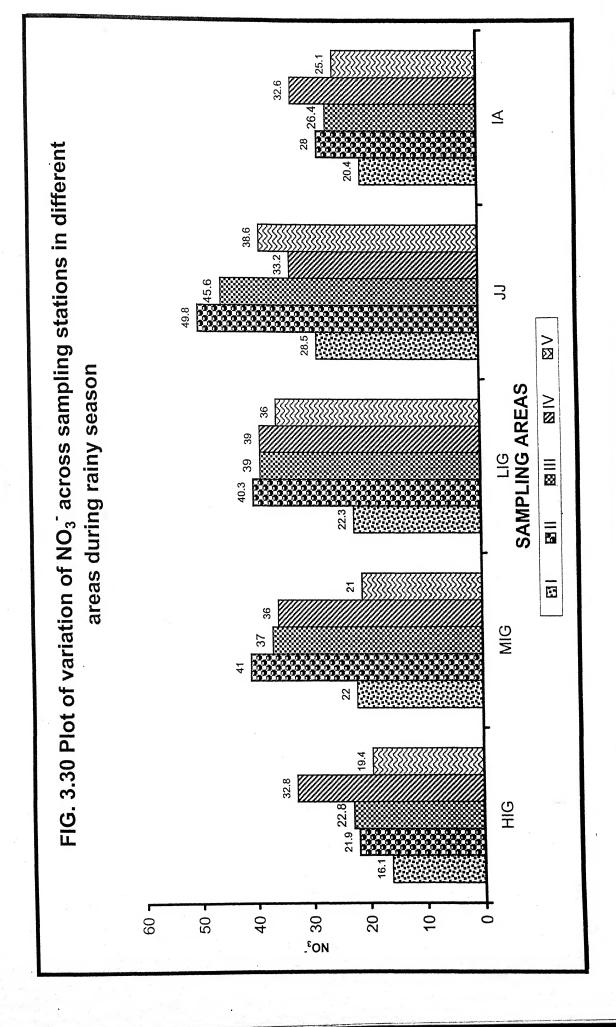


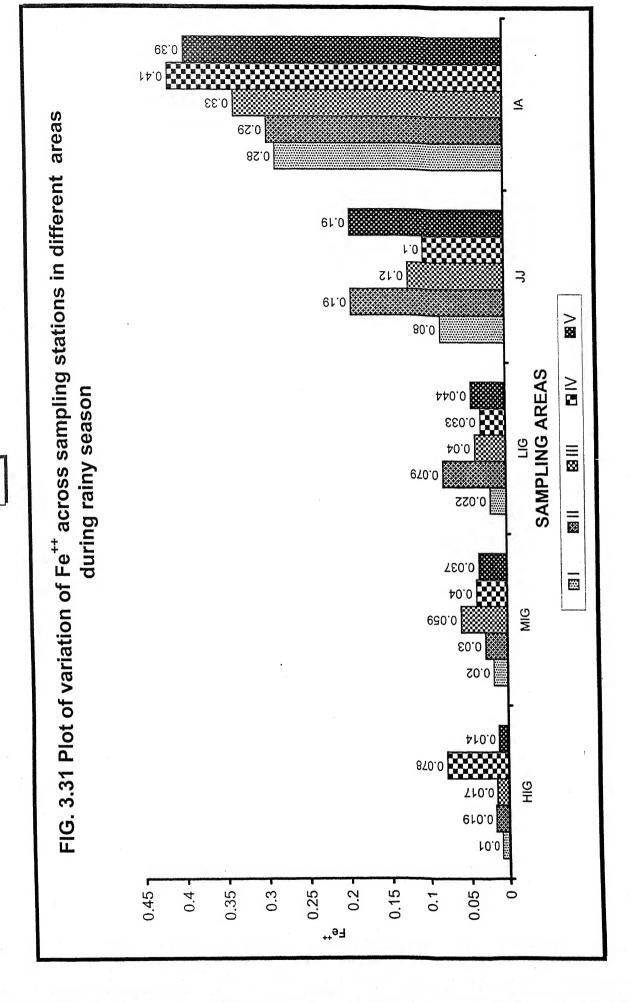


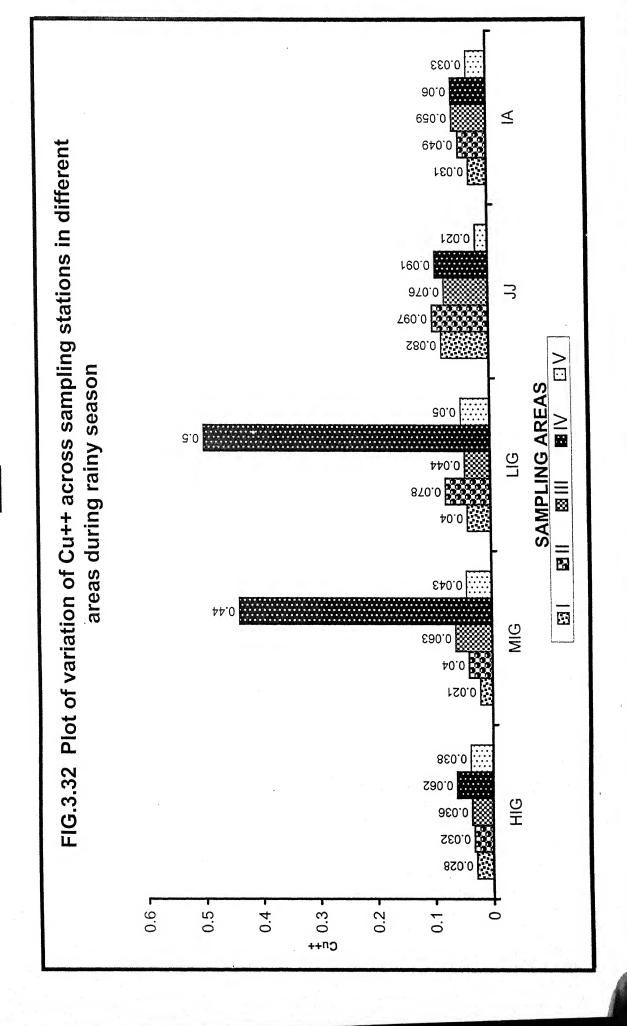


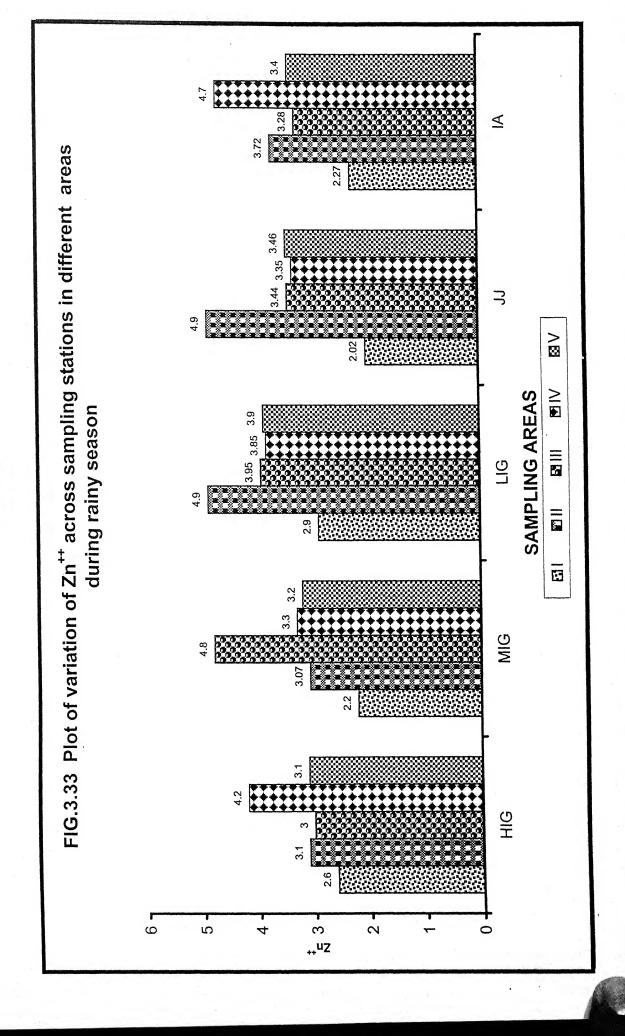


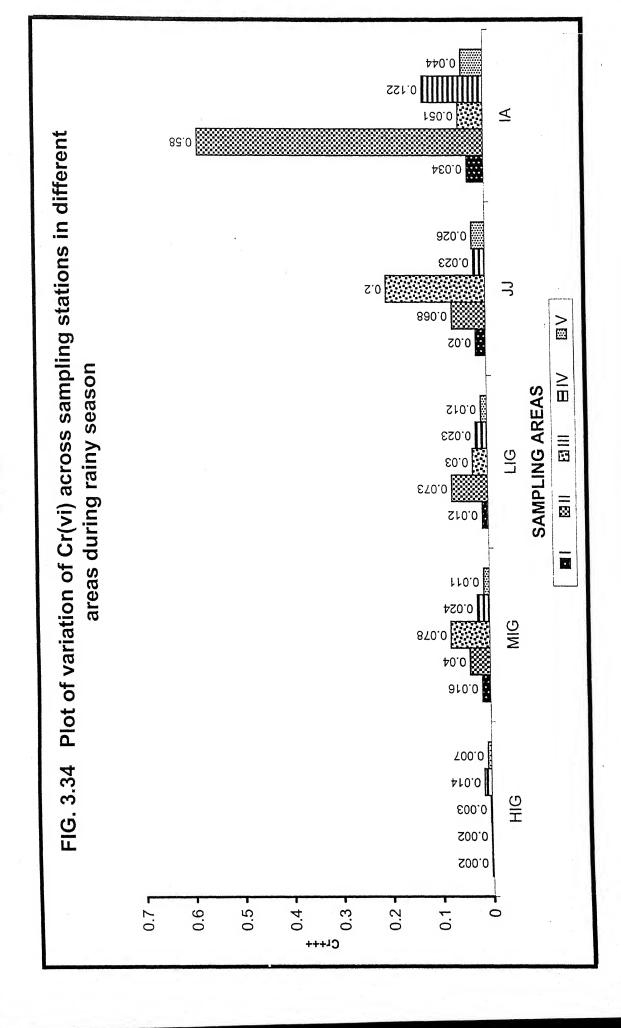


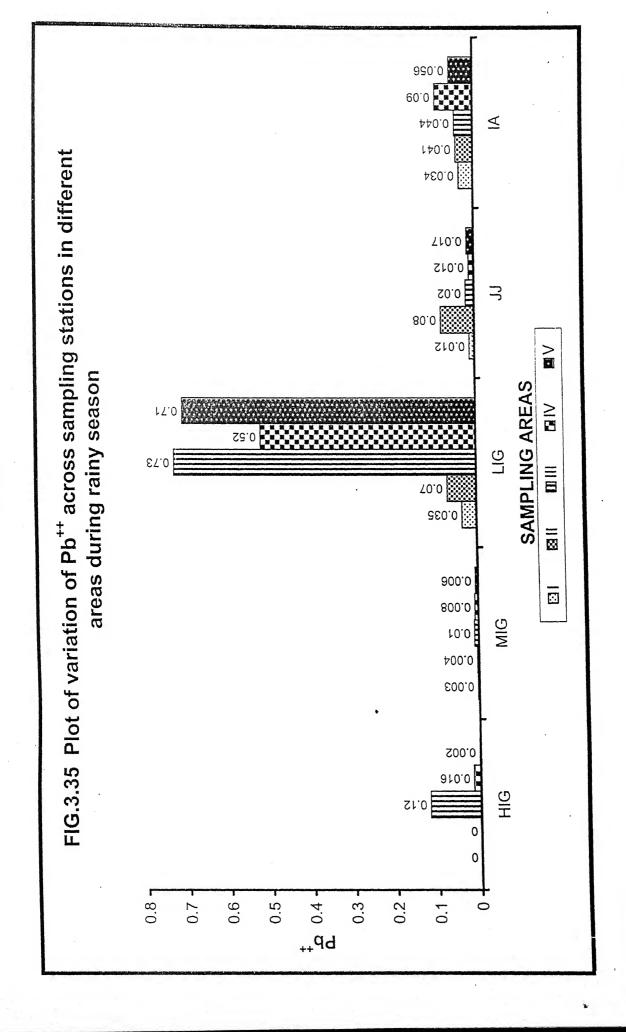


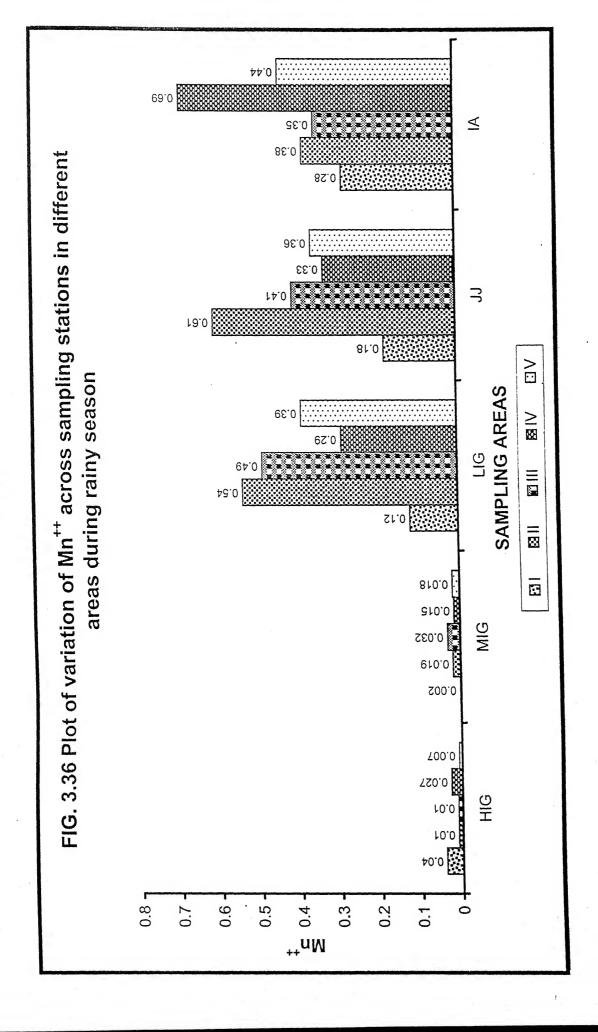


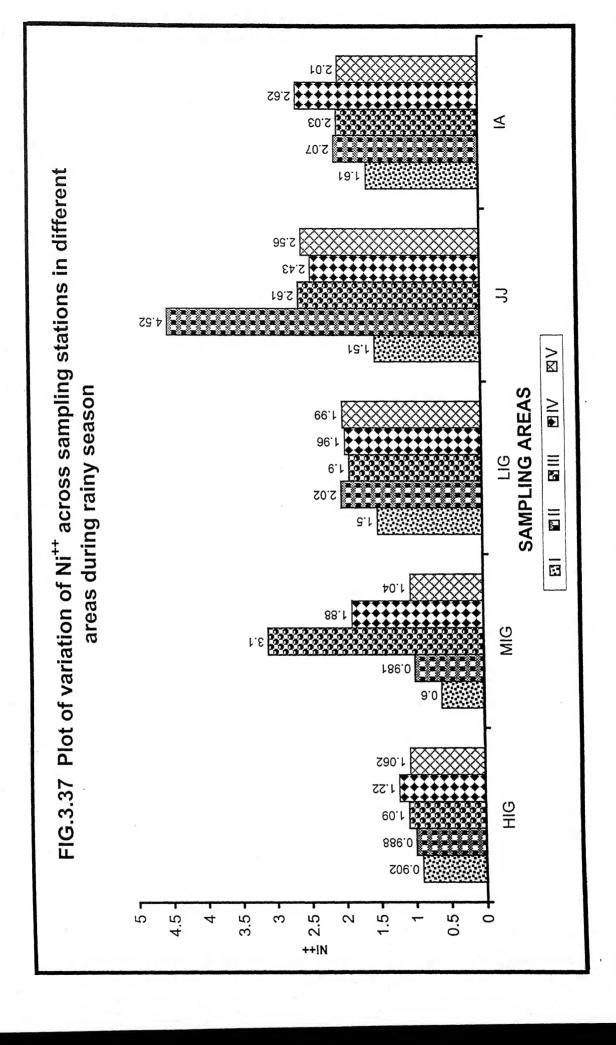


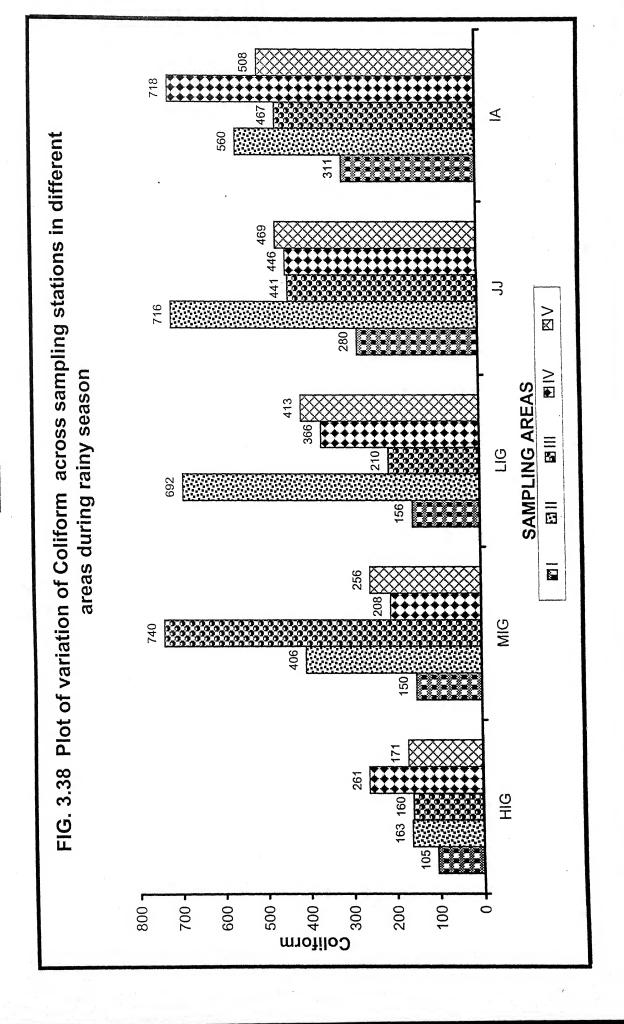












(c) Low Income Group Sampling Stations:

Tables 3.17 and 3.18 and figures 3.21 and 3.39 containing the relevant data clearly indicate that LIG-II sampling station at Fazalganj has the worst problem of groundwater pollution considering the physicochemical parameters and heavy metal concentration. It is obviously due to location of some factories and truck repair workshops all around the sampling station.

The groundwater samples from LIG-I, Ratanlal Nagar are the best in the LIG residential group considering the fact that the majority of more important parameters are favourable from the point view of potability of water. The groundwater sampling station LIG-III Babupurwa, LIG-IV, LIG, 1367 AV3, Kalyanpur, LIG-V Barra-I appears to occupy intermediate position from this point of view.

(d) Jhuggi Jhopri residential area sampling stations.

Among the five sampling stations selected for investigation in the JJ clusters, the one located at Railway gate, Saipuram in Jhakkerkatti (JJ-I) seems to have least contaminated groundwater though it, too, is not potable enough for general population living in these areas. The worst groundwater appears to originate from sampling station at 12 Block, Kachchi Basti, Govind Nagar, Loharan Ka Bhatta, near J.K. Tample i.e. JJ The F-, NO³⁻ and the more harmful Cr+++, Mn++ and coliform are much above the permissible limit. The potability of water can only be improved if concentration these harmful ions/ species is brought down to safe levels.

To a lesser extent, the same can be stated about the quality of ground water of sampling station at JJ-III (Shivraj Singh Ka Purwa, Near J.K. Temple) JJ-IV (Ram Surat, Loharan Ka Purwa behind J.K. Temple and JJ-V Loharan Ka Purva, near J.K. Temple. Tables 3.19 and 3.20 as also figures 3.21-3.29 summarise the data graphically.

(e) Industrial area sampling stations.

In the residential part of different industrial areas, the one at 5A, Wajidpur, Jajmau i.e. IA-IV was found to be the worst as most of the parameters and concentrations tended to reach their maximum at this sampling station. The high concentration of Cr+++, Fe++, Cu++, coliform etc. is due the presence of a large number tanneries in the vicinity of the sampling station. The same can be said about other sampling stations the IA to lesser extent. Among the five groundwater from IA-I, the one near Bank of Baroda, Panki is the best from the point of view of potability though it too leaves much to be desired. Table 3.21 and 3.22 and figure 3.21 and 3.39 summarise the data obtained for the industrial area sampling station.

On the basis of our studies one can say that the quality of groundwater from the point of view of potability is satisfactory in HIG and MIG residential areas. It is on the borderline in LIG areas while that in JJ and IA residential areas, it is definitely worse as borne out by our study.

Seasonal variation in physiochemical parameters in various areas in groundwater of Kanpur City in different seasons from May2002 to April 2003. Table 3.11

	Winter	7.22	1979	1029	724	1520	871	650	242	169	204	374	1.92	35.5
												-		
IA	Rainy	8.35	2055	1202	515	1515	871	946	246	176	235	624	1.78	26.5
	Summer	7.73	1432	925	491	714	406	308	160	88	156	177	1.64	29
	Winter	7.25	2015	1012	549	917	397	519	121	149	189	223	1.80	393
JJ	Rainy	7.88	1733	1157	491	210	387	557	141	135	215	323	1.74	39.7
	Summer	7.44	1425	885	529	513	237	276	102	09	146	135	1.51	23.9
	Winter	7.28	2059	986	069	321	194	127	58	33	160	151	1.72	2.8
LIG AREA	Rainy	7.47	1708	1096	469	329	180	148	59	46	194	166	1.71	35
	Summer	7.12	1419	846	495	326	181	132	59	41	134	89	1.38	18
	Winter	7.94	2185	657	909	250	120	129	46	34	147	111	1.6	32.5
MIG AREA	Rainy	7.99	1279	917	423	268	122	145	43	37.25	125	151	1.6	33
	Summer	7.78	149	70	412	261	129	140	45	37	06	83	1.5	17
	Winter	8.00	1212	611	134	227	123	100	44.4	28.12	134	92	1.5	26.6
HIG AREA	Rainv	7.98	1556	808	149	257	147	108	46	32.8	181	145	1.58	22.7
	Cummer	7.84	1167	766	142	248	135	113	46.7	29.6	81.4	64	1.08	11.9
	**	Variable	EC	TDS	T.Alk	T.H	Temp.H	Perm.H	Ca**	Mg**	. SO4	.T	ČX.	NO ₃

173

Table - 3.12

Seasonal variation in heavy metal concentration and MPN in groundwater of Kanpur Metro from May 2002 to April 2003.

	Winter	.325	.63	4.24	0.62	.057	.284	1.03	456
ΙΑ	Rainy	.34	.05	3.57	0.072	.052	.40	2.09	514
	Summer	.32	620.	3.37	0.36	.02	680.	1.52	230
	Winter	.19	.061	4.35	.061	.073	.22	1.03	431
JJ	Rainy	.12	.087	3.44	990.	.026	80.	2.52	171
	Summer	.14	60.	3.13	.035	.021	620.	1.47	232
	Winter	.068	.027	4.40	.061	980.	.112	1.05	576
LIG AREA	Rainy	.043	.049	3.9	.075	.056	.380	1.88	406
	Summer	.052	.018	3.4	.042	.043	.064	1.37	316
	Winter	90.	.053	4.4	.019	200.	.016	.72	575
MIG AREA	Rainy	.037	.042	3.5	.028	900.	.017	1.01	352
	Summer	.046	.023	3.22	.016	.003	0.021	1.17	307
	Winter	.059	1010	3.6	800°.	600.	.010	.91	170
HIG AREA	Rainy	.027	.039	3.2	.018	.002	.012	1.08	192
	Summer	.03	.012	2.9	.012	700.	.017	.75	111
	Variable	Fe++	Cu**	Zn**	Cr3+	Pb2+	Mn ²⁺	Ni2+	Coliform

Table 3.13

Variation of physicochemical parameters across the sampling stations in HIG residential areas during the rainy season.

Parameter	HIG-I	HIG-II	HIG-III	HIG-IV	HIG- V
рН	7.90	8.08	7.81	7.98	7.89
EC	1506	1554	1568	1608	1544
149 TDS	694	716	802	856	806
257 T Alk.	129	156	140	169	151
Т.Н	201	256	277	313	237
Ca++	47.2	51.8	57.6	65.4	50.4
Mg++	22.3	25.3	24.7	33.4	29.3
SO ₄	142	208	183	258	156
Cl-	97	104	104	190	146
F-	1.33	1.54	1.56	1.86	1.64
NO ₃ -	16.1	21.9	22.8	32.8	19.4

TABLE 3.14

Variation of heavy metal concentration and MPN index across sampling stations in HIG residential during the rainy season.

Parameter	HIG-I	HIG-II	HIG-III	HIG-IV	HIG- V
Fe++	0.11	0.019	0.017	0.78	0.014
Cu**	0.028	0.032	0.036	0.062	0.038
Zn**	2.6	3.1	3.0	4.2	3.1
Cr+++	0.002	0.002	0.003	0.014	0.007
Pb++	0.000	0.000	0.012	0.016	0.002
Mn++	0.0004	0.10	0.010	0.027	0.001
Ni.++	.902	.988	1.09	1.22	1.062
Coliform	105	163	160	261	171

Table 3.15

Variation of physicochemical parameters across the sampling stations in MIG residential areas during the rainy season.

Parameter	MIG-I	MIG-II	MIG-III	MIG-IV	MIG- V
рН	7.92	7.78	806	8.04	7.97
EC	4.78	1209	2374	1059	1269
TDS	855	790	1149	848	908
T Alk.	313	400	523	448	421
Т.Н	238	293	202	268	239
Ca++	46.8	49.6	58.6	42	52.6
Mg++	32.8	36.2	45.2	39.8	40.9
SO ₄	63	101	266	106	108
Cl-	96	115	218	176	145
F-	1.4	1.44	1.86	1.8	1.4
NO ₃ -	22	41	37.0	36	21

TABLE 3.16

Variation of heavy metal concentration and MPN index across sampling stations in MIG residential during the rainy season.

Parameter	MIG-I	MIG-II	MIG-III	MIG-IV	MIG- V
Fe ⁺⁺	0.020	0.030	0.059	0.040	0.037
Cu++	0.21	0.040	0.063	0.044	0.043
Zn++	2.2	3.07	4.8	3.3	3.2
Cr+++	0.016	0.040	0.078	0.024	0.011
Pb++	0.003	0.004	0.010	0.008	0.006
Mn++	0.002	0.019	0.032	0.015	0.018
Ni.++	0.060	.981	1.31	1.18	1.04
Coliform	150	406	740	208	250

Table 3.17

Variation of physicochemical parameters across the sampling stations in LIG residential areas during the rainy season.

Parameter	LIG-I	LIG-II	LIG-III	LIG-IV	LIG- V
рН	7.01	7.93	7.52	7.42	7.48
EC	1218	2416	1624	1692	1611
TDS	998	1291	1026	1065	1101
T Alk.	438	501	487	446	468
T.H	306	353	340	318	327
Ca++	68.9	100	72.8	76.4	61.23
Mg++	29.2	45.9	31.5	34.2	37.6
SO ₄	153	248	188	187	196
Cl-	125	203	180	152	168
· F-	1.50	1.72	1.80	1.66	1.73
NO ₃ -	230	40.3	39	39	36

TABLE 3.18

Variation of heavy metal concentration and MPN index across sampling stations in LIG residential during the rainy season.

Parameter	LIG-I	LIG-II	LIG-III	LIG-IV	LIG- V
Fe++	0.028	0.079	0.040	0.033	0.44
Cu++	0.040	0.078	0.044	0.044	0.50
Zn++	2.9	4.9	3.95	3.85	3.9
Cr+++	0.012	0.073	0.030	0.023	0.012
Pb++	6.035	0.070	0.073	0.052	0.071
Mn++	.21	0.54	0.49	0.29	.39
Nr.++	1.50	2.02	1.90	1.96	1.99
Coliform	156	692	210	366	413

Table 3.19

Variation of physicochemical parameters across the sampling stations in JJ residential areas during the rainy season.

Parameter	JJ-I	JJ-II	JJ-III	JJ-IV	JJ-V
рH	7.24	8.54	7.60	8.16	7.86
EC	4510	1956	17.50	1716	1734
TDS	937	1377	1178	1136	1152
T Alk.	471	520	498	484	490
т.н	804	1016	937	883	906
Ca++	104	259.8	113.2	100	117
Mg++	56.6	259	112	151	118.6
SO ₄	180	257	224	206	212
Cl ⁻	248	451	342	301	325
F-	1.50	1.94	1.80	1.68	1.78
NO ₃	28.5	49.8	45.6	33.2	38.6

TABLE 3.20

Variation of heavy metal concentration and MPN index across sampling stations in JJ residential during the rainy season.

Parameter	. JJ-I	JJ-II	JJ-III	JJ-IV	JJ-V
Fe ⁺⁺	.08	.19	.12	.10	.19
Cu++	0.082	.097	.076	.091	.02
Zn++	2.02	4.9	3.44	3.35	3.46
Cr***	.0250	.068	.020	.023	.026
Pb++	.012	.080	.020	.012	.017
Mn++	.18	.61	.41	.33	.36
Ni.++	1.51	4.52	2.61	2.43	2.56
Coliform	280	716	441	446	469

Table 3.21

Variation of physicochemical parameters across the sampling stations in IA residential areas during the rainy season.

Parameter	IA-I	IA-II	IA-III	IA-IV	IA-V
pН	7.66	8.10	8.32	9.04	8.50
EC	1948	2004	2203	2663	2648
TDS	1092	1181	1223	1392	1206
T Alk.	471	508	522	570	514
т.н	1204	1510	1620	1828	1510
Ca++	142.6	180.3	230	314	221.6
Mg++	73.3	92.9	165.3	172.4	100.2
SO ₄	185	260	230	289	210
Cl-	417	721	528	721	524
F-	1.61	190	1.60	2.10	1.79
NO ₃ -	20.4	28.0	26.4	32.6	25.1

TABLE 3.22

Variation of heavy metal concentration and MPN index across sampling stations in JJ residential during the rainy season.

Parameter	IA-I	IA-II	IA-III	IA-IV	IA-V
Fe++	.28	.29	.33	.41	.39
Cu++	.031	.049	.059	.060	.033
Zn++	2.27	3.72	3.28	4.7	3.4
Cr***	0.034	0.058	0.051	0.122	0.044
Pb++	0.034	.041	.044	.090	.056
Mn++	.28	.38	.35	.69	.42
Ni.++	1.61	2.07	2.03	2.62	2.01
Coliform	3.11	560	4.67	718	505

TABLE 3.23

Variation Standards of Physical and Chemical Quality of potable water* during the rainy season.

Parameter	Prescribed ISI 15:10500-198	Prescribed ICMR (1975)	Prescribed WHO (1984)	Prescribed USPHS (1975)
pН	6.5-8.5	7.0-8.5	6.5-9.2	6.0-8.5
EC	-	-	-	300
TDC\S	500	-	500	500
Alkalinity	-	-	-	-
TH	300	-	500	-
Ca	75	-	200	100
Mg	30	-	150	30
Sulphate	150	200	400	250
Chloride	250	200	500	250
Fluoride	0.6-1.2	1.0	3.0	1.5
Nitrate	45	20	45	10
Phosphate	1.0	-	-	0.1
Colifom	<500	-	100	100
Na	-	-	200	-
Fe	<0.03	0.1	1.0	<0.3
Cu	-	0.05	1.5	1.0
Cd	0.01	0.01	0.01	0.01
Cr(VI)	0.05	-	0.05	0.05
Zn	-	5.0	5.0	5.5
Pb	**	0.05	0.1	0.05
Mn	0.1	0.1	0.5	0.05
As	0.05	-	0.05	0.05
Hg	0.01	-	0.01	0.02

^{* .. 35}only numerical values. EC is in . μ mhos/com. Coliforms as MPN counts and all after parameters are in mg/I or ppm.

REFERENCES

- Agarwal Shankar G, Chandrawanshi Ghandra K, Patel Raj M, Agarwal Smita, Kamavisdar Anand, Mundhara Girdhar L. (2001) Acidification of surface water in central India Water Air Soil Polln, 130(1-4), 855-862.
- 2. Ravichandra S. Pundarikanthan NV, (1991) Studies on ground water quality of Madras. Indian J Environ Hlth, 33 (4), 481-487.
- 3. Latha MR, Indirani R, Sheeba S. Francis Honora J. (2002)
 Groundwater quality of Coimbatore district, Tamil Nadu. J. Ecobio, 14(3), 217-221.
- 4. Sarma HP, Bhattacharyya KG, (2001) Quality of drinking water of tubewells and municipal supply waters with respect to Na, K, Ca, Mg and Fe in the Darrang district. Indian J Environ Prot, 21(11)1006-1011.
- 5. Ramaswami, V. & Rajguru, P., 1991, 'Groundwater quality of Tirupur,' Indian J. Environ. Hlth., 33(2), 187-191
- 6. Subbarao, N. & Krishna Rao, R., 1991, 'Groundwater quality in Vishakhapatnam urban area. Andhra Pradesh', Indian J. Environ. Hlth. 33(1) 25-30.
- 7. Gupta, A.K. & Saxena, G.C., 1996, 'Evaluation of groundwater pollution potential of Agra due to demo-economic factors', IJEP, 16(6),419-422.
- 8. Ravichandran, S. & Pundarikanthan, 1991, 'Studies on groundwater quality of Madras', Hlth., 33(4), 481-487.
- 9. Hegde, S.G., et al. 1992, 'Groundwater quality deterioration in Hubli city area', Indian J. Environ. Hlth., 34(2), 138-142.

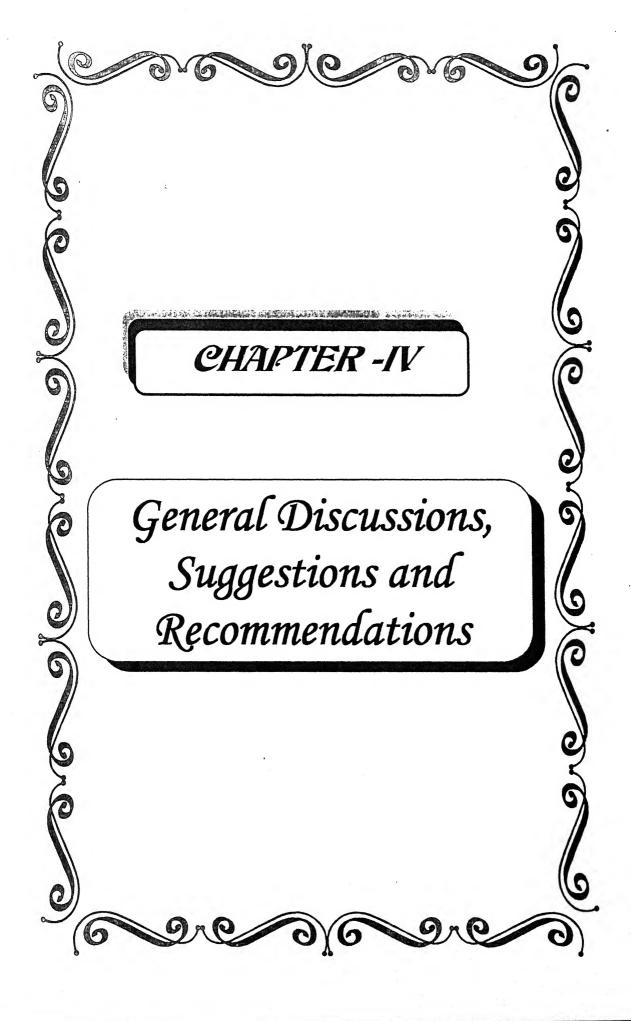
- 10. Tripathi, I.P., et al., 1995, 'Analysis of trace element in water from hand pumps of Rewa city', IJEP, 16(5), 321-327.
- 11. Suresh, I.V., et al., 1996, 'Fluoride concentration in Bhopal water resources', Ecol. Env. & Cons., 2(11-15).
- 12. Sharma, S. & Mathur, P., 1994 'Bacteriological quality of groundwaters in Gwalior', IJEP, 14 (2), 905-907.
- 13. Jain, C.K., et al., 1996, 'Groundwater quality in western Uttar Pradesh', Indian J. Environ. Hlth., 38(2), 105-112.
- 14. Quasim, S. & Burchinal, J.C., 1970, 'Leaching from simulated landfills', J.Wat. Pollut. Cont. Fed., 42(3).
- **15. Das, P.,** et al., 1997, 'Leachate production at sanitary landfill', J.Amer. Soc. Civil Engg., **103, EE2.**
- **16.** Haynes, R., 1982, Envtl. Sci. Methods, Champman and Hall, London.
- 17. Kenneth, E.F., 1976, Principles of Envtl. Sci., Mc Graw Hill Book Company, NY, USA.
- 18. Parker, C.R., 1972, 'Water Analysis by Atomic Absorption Spectroscopy, Varian Techtron Pvt. Ltd., Australia.
- **19. APHA,** 1991, Standard Methods for the Examination of Water and Waste Water, 19th Ed., APH Association, Washington DC.
- 20. Trivedi, R.K. & Goel, P.K., 1986, Chemical and Biological Methods for Water Pollution Studies, Envtl. Publs., Karad.
- 21. Vermani, O.P. & Narula, A.K. 1989, Applied Chemistry Theory and Practices, Wiley Eastern Ltd.

- **22. Perez, A.S.,** et al., 1993, 'Simultaneous determination of Cu, Fe, Mn and Zn in Bovine Lines and estuary sediment', Anal. Letl., **26**(4), 271.
- 23. Bhand, S.G. & Chaturvedi, K.K., 1995, 'AAS and ASV in detection and speciation of cations', IJEP, 15(6),, 426-429.
- **24.** Babbitt, H.E. & Donald, J.J., 1955, Water Supply Eng., 5th Ed. Mc Graw Hill & Co., London.
- 25. Rai, J.P.N. & Sharma, H.C., 1995, 'Bacterial contamination of groundwater in rural areas of NW Uttar Pradesh', Indian J. Environ. Hlth., 37(1).
- 26. Sharma, S. & Mathur, R., 1994, 'Bacteriological quality of groundwater in Gwalior', IJEP, 14 (12), 905-907.
- **27. Kataria, H.C.,** 1995, 'The pH measurement in borewell water of Bhopal city', IJEP, **15**(5), 350-352.
- 28. Babbit, H.E. & Donald, J.J., 1955, 'Water Supply Engineering', 4th Ed. Mc Graw Hill & Co., London.
- **29. NCC,** Committee on Biology Effect of Atmospheric Pollutnts, Fluorides, Nat. Acad. Sci., Washington DC.
- **30.** Tyagi, O.D. & Mehra, M., 1990, A Text Book of Environmental Chemistry, Anmol Publ., New Delhi.
- 31. Sax, N.I., Industrial Pollution, Van Nostrand Reinhold Company, New York.
- **32.** Correa, P., et al. 1964, A Model for Gastric Ulcer Epidemiology, Lancet, 2158-59.
- 33. Bawsworth, G., et al., 1975, 'Possible relationship among nitrates and nitrosamines and gastric cancer inSW Colombia', Scientific Publication M No.9, Lyon, France.

- 34. Pandey, S.P., & Hasan, M.Z., 1979, J. Inst. Engineers India,61, 53.
- **35. Sharma, D.K.,** *et al.*,, 1988, Ind. Wat. Works Assoc., Jly-Sept., 257.
- 36. Dang, H.S., et al., 1984, Indian J. Env. Hlth., 26, 151.
- 37. Handa, B.K., et al., 1983, IAWPC Tech. Annual., 10, 167.
- 38. MIN, 1980, Annual Report, Hyderabad, p.26.
- **39. Kausik, N.K. & Prasad, D.K.,** 1964, 'Seasonal variation in coliform and entercoccus organisms in well waters', Eng.Hlth.,**6**, 251.
- **40. Thapliyal, D.C.,** et al., 1972, 'The bacteriological quality of Tarai Waters', Indian J.Environ. Hlth., **14** (I), 88-94.
- **41. Godbole, S.H. & Wable, M.,** 1981, 'Sanitary survey of public eating places in Pune: Bacteriological examination of drinking water and food samples', Indian J.Environ. Hlth. **23**(2), 134-141.
- **42.** Narayana, K.L. & Rao, P.S.H., 1981, Warangal well waters-Bacteriological quality, Indian J. Enviorn. Hlth., **23**(2),148-151.
- **43.** Battacharjee, J.W., et at., 1989, 'Bacteriological quality of drinking water in rural India', J. Indian Wat. Wks. Assoc., **21**, 185-190.
- **44. Srivastava, A.K.,** et al., 1989, 'Data linkage correlations of morbidity and mortality in relation to bacteriological quality of water at Nagpur', IJEP, **9**(9).

- **45. Jain, O.P.& Modi, S.,** 1991, 'Seasonal succession in hydrography of well water of Bhopal district with reference to draught conditions', J.Nateon., **3** (1),76-90.
- **46. Kaur A 1982,** 'Seasonal variability of Chemical parameters in drinking water from shallow aquifers', IJEP **12**(6), 409-415.
- **47. CPCB Nov.** 1997, 'Groundwater quality in Kanpur'.





GENERAL DISCUSSIONS, SUGGESTIONS, AND RECOMMENDATIONS

4.1 INTRODUCTION

Water is the essence of life. We have cried foul on multinational companies in India marketing cola and other soft drinks containing pesticides. However, the presence of extent of pesticides in cola and other soft drinks pales into insignificance if we consider the extent of pollution of groundwater in Indian cities. We take pride in the fact that bottled mineral water (of doubtful purity again) is available everywhere. There is piped water supply of treated water in almost all the cities. But do we realise that still a vast majority of our population has, per force to depend on groundwater, that too untreated, to meet their daily requirements including drinking and cooking? Is there any justification for use of polluted groundwater by them?

In our studies on quality of groundwater in Kanpur metro, we have observed that even the groundwater in HIG areas, which are supposed to be cleaner with healthy surroundings, is sometimes polluted to extent that in it becomes unpotable at of some of the sampling stations.

The less said about the groundwater available in LIG, JJ and IA areas the better.

In fact the ground water is JJ cluster IA residential area is so polluted that it can be emphatically stated that population there should not be allowed to use the groundwater for drinking and cooking purposes. Water for their use should supplied by other means.

One of the most effectives suggestions to dilute the impurities present in groundwater is rain-water harvesting i.e. artificial recharge.

Let us first look into background information before the actual rain water harvests system is described in detail.

4.2 Groundwater Storage

Groundwater is the largest source of fresh water stored in the earth. Fresh water lakes hold about 120,000 km³ of water. The estimated amount of surface water is 120,000 km³ and that of groundwater to a depth of .8km into the crust of the earth, is about 4×10^6 km³. Additional 14×10^6 km³ of ground water occurs at depths from 0.8 to 3.2 km under less favorable condition in terms of economic accessibility and chemical suitability for common uses. This underground storage constitutes a vast and almost ubiquitous resource for satisfying water requirements of all kinds. Moreover, additional storage under the surface of the soil, if properly utilized, increases the available water resources by impounding it for future use which would otherwise be lost through evaporation or run off. Groundwater is often the only source of water in arid and semi-arid

regions of the earth and in such regions, it is of fundamental importance to any social or economic development. In humid parts of the world where rivers and lakes have supplied much of the water needed by man, the value of groundwater has tended to be overlooked. In recent years, however, as surface water resources have been given way to groundwater resources, groundwater constitutes a major source of water supply in many tropical countries.

In the past, knowledge of groundwater was not only meager but often misleading and it was considered as something hidden and mysterious requiring near magic practices for its prospection. Technologically breakthrough in last 25 years have developed effective methods and tools for hydrological research and exploitation and, therefore, for the understanding of groundwater. These advances in technology have resulted in enormous increase in the extraction of groundwater all over the world. Currently drilling machines have made it possible to reach thousands of meters and more even in hard rocks, below the land surface, in search for groundwater. However, in some areas where natural replenishment of groundwater is inadequate, to keep pace with accelerated water demands, the amount of water occurring naturally in storage is decreasing substantially, In general terms, storage is the act of accumulating water in subsurface geological formation for future use. This act is either natural or due to human effort. The economic cost of groundwater storage depends on whether it is natural, induced or created.

4.2.1 Groundwater Reservoir Systems

Natural drainage of water occurs through either surface drainage systems such as rivers and glaciers or through groundwater drainage system. Rivers as well as groundwater systems hold a certain volume of water in storage. A salient difference in the two classes of drainage systems is expressed by storage/discharge ratio, which is defined as the volume of water in storage divided by the annual discharge of the system.

In case of a rivers, the volume of water stored in a riverbed is almost negligible as compared to the annual discharge of the river. While in groundwater system, the volume of water in storage is much larger than the usual discharge from the systems. This is explained as follows-

Example 1: The storage/discharge ratio of a river 100 km long, 3 m deep and 60 m wide discharging 6000 million m³/year may be represented as follows-

$$\frac{\text{Storage}}{\text{Discharge}} \text{(surface water)} = \frac{18 \times 10^6}{6 \times 10^9} = \frac{3}{1000} = 0.003$$

Example 2: A smaller groundwater system, which is 50 m wide, 10 km long and 60 m thick and has an effective porosity of 15 per cent and having an annual discharge of 100 million m³/year has storage-discharge ratio as follows-

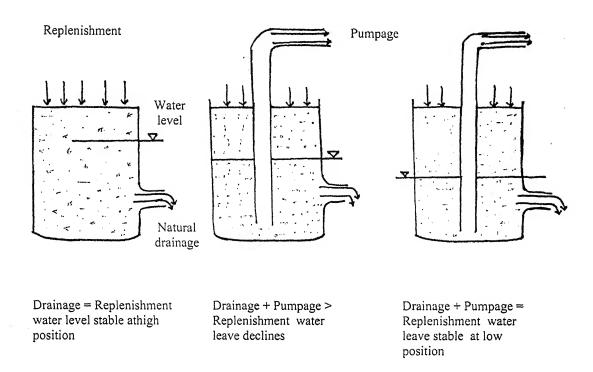
$$\frac{\text{Storage}}{\text{Discharge}} \quad \text{(groundwater)} = \frac{4.5 \times 10^9}{1 \times 10^8} = \frac{45}{1}$$

The importance of these cases can be explained as, in the absence of any rainfall if waters were extracted from the systems at the rate to their corresponding respective average annual discharges, the river system would dry up only 1 day (0.003 year), but the groundwater system would dry up only after about 45 years. Thus groundwater resources will last longer than surface ones.

A groundwater reservoir system may be represented by a tank (Fig. 4.1) of irregular shape filled with granular material and provided with a lateral outlet somewhat above its bottom. The irregular shape simulates the boundaries of an unconfined reservoir, the granular material simulates the aquifer and the outlet simulates the mechanism of natural discharge. Replenishment is simulated by pouring water into the tank from the top. The tank fills up, the water level slowly rises and water begins to move from the outlet. If it is assumed that replenishment is continuous and constant, the following cases arise:

a. Natural Drainage Natural Replenishment

In this situation since the drainage is equal to natural replenishment, at the end a state of dynamic equilibrium is reached and water level remains stable at high position.



b. Drainage + Pumpage> Replenishment

In most natural aquifers, the regulative resources are very large and it takes years to reach a new equilibrium state. During all these years, the water level continues to decline and the groundwater system is in a state of non-equilibrium.

c. Drainage + Pumpage = Replenishment

In this state the new equilibrium state is reached and the water table becomes stable at position. Thus, the water which is

artificially recharged to the aquifer can be stored underground over considerable, through not indefinite time.

4.3 Artificial Recharge

With the increasing use of groundwater for agricultural, municipal and industrial needs, the annual extractions of groundwater are far in excess of net average recharge from natural sources. As a result, groundwater is being withdrawn from storage and water levels are declining, resulting in crop failures, adverse salt balance, sea water intrusion in coastal aquifers and land subsidence in areas where drafts results in compaction of sediments. Artificial recharge¹ is a replenishment of groundwater reservoirs as a result of man's activities. It is accomplished by augmenting the natural infiltration of precipitation or surface water into underground formation by deliberate or incidental human activities.

4.3.1 Objectives And Basic Principle

Artificial recharge projects are designed to conserve water for further use. The main objectives of recharging are:

1. Control of Salt Water Encroachment

In coastal areas of the world, notably Israel, the Netherlands and California, artificial recharging systems are used to block inland encroachment of seawater. The system involves the injection of fresh water through wells in order to build up a pressure barrier that will retard or reverse encroachment of salty water that has but serves as a hydraulic mechanism for better use of existing ground waster reserves.

2. Disposal of Liquid Waste

Sanitary sewage and liquid wastes of industrial sites may be placed into artificial recharging facilities after treatment through spreading areas or special basins or pits.

3. Filtration of Water

Artificial recharging helps in filtration of surface water which otherwise may have suspended solids, biological and chemical impurities, dissolved air and gases, *etc.*

4. Control of Subsidence

Heavy withdrawals of groundwater results in subsidence of the surface of the land. This could be overcome by forcing water under pressure into groundwater reservoirs.

5. Recovery of Oil from Partially Depleted Oil Fields

In this approach oil is forced through the ground towards producing wells by hydraulic head of water built up around artificial recharge wells which drives the oil through the geological formation towards the oil production well.

For selecting the adequate site and the type of recharge a through knowledge of the following is essential:

Geological boundaries

Storage capacity

Inflow and outflow of waters

Hydraulic boundaries

Porosity

Hydraulic conductivity

Transitivity

Natural discharge of springs

Water resources available for

Natural recharge

recharge

Water balance

Lithology

Depth of aquifer

Technotic boundaries.

Aquifers best suited for artificial recharge are those which absorb large quantities of water and do not release them too quickly. In general, the areas which are selected for artificial recharge projects are those where water table levels are lowered as a result of draught or as a result of a deficit in natural recharge.

4.3.2 Methods Of Artificial Recharging

1. Spreading Basins

The method implies the passage of water from the surface of the soil through the non-saturated zone of the soil and the geological strata to the saturated part of the aquifer. Spreading basins must be selected or constructed in order to have an approximately flat bottom, which is to be covered evenly by small quantities of water. This technique needs large surfaces of land for the recharge works. Spreading grounds are arranged in networks so that excess water from the higher basin escapes into the nearest lower one. Basin type recharge project (Fig. 4.2) is designed for the purpose of spreading storm waters and has an advantage that silt problem can be alleviated by using part of basins for settling. Experiments in California recharge area showed that the silt content was reduced from 3000 ppm to 250 ppm by one settling pond. The rate of settling can be increased by using chemicals called flocculants.

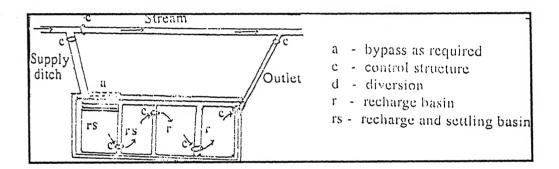


Fig. 4.2 Recharge system - basin type

2. Ditch and Flooding Type Recharge

The ditch technique required less soil preparation and is also less sensitive to silting because a part of the suspended matter can be rejected out together with residual water. Several layouts are used for this system (Fig. 4.3) Such as divided **canals system** in which the main channel is subdivided into two ditches, each of these again into two others, *etc.*; the ditches becoming progressively smaller. In **contour ditch system**, the ditch follows

approx. the contour of the ground in a fashion of closely coiled snakes.

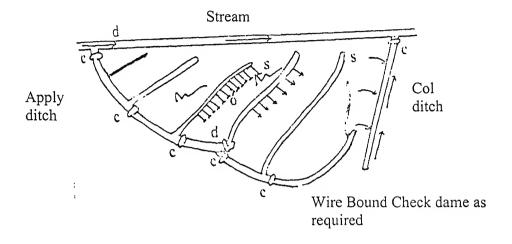


Fig. 4.3 Recharge system - Ditch and flooding type

In the flooding type recharge system, this sheet of water is made to flow over the land surface and the native soil should not be disturbed, except for small arrangements.

3. Pits and Injection Wells

This system is usually used in projects where land is scarce or where shallow impervious overburden is found.

In pits infiltration occurs laterally through the walls of the pit because in sedimentary or alluvial material the horizontal hydraulic conductivity is considerably large4r than the vertical. Recharging rates of 20 ml/day was noticed in the first 1/17 hectare of Peoria pit (Fig. 4.4) at Illinois, USA.

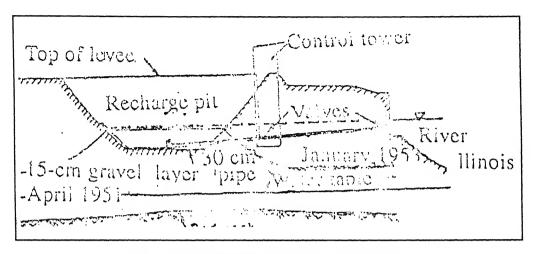


Fig. 4.4 Recharge System - Pit type

Injection wells are purposely drilled or excavated below the level of the water table. These are used in locations where a thick impervious layer exists between the surface of the soil and the aquifer to be replenished. These are also advantageous when land is scarce as in urban areas. Water injected in these pits must be of drinking standard.

4.3.3 Quality Of Water For Recharging

The quality of injected water is very important for recharging. Suspended solids, biological and chemical impurities, dissolved air and gas, turbulence and temperature of both the aquifer and the injected water have an effect on the life and efficiency of a well by clogging or corrosion. Large amounts of dissolved air in the recharge water reduces the permeability of aquifer by air binding. The injected water should have temperature only slightly higher than the temperature of aquifer.

A major requirement for water to be used in recharge projects is that they be silt free. Silt is the content of undissolved solid matter, measured in mg/l, which settles in stagnant water with velocities less than 0.1 m/hr. It includes materials such as clay particles, organic matter and fine particles of calcite. Higher silt content of about 25000 mg/l have been observed in seasonal rivers with average silt content varying from 3000 mg/l to 8000 mg/l during flooding times. As soon as water becomes stagnant the silt load settles down. The speed of settling is governed by the size and weight of the suspended particles and by electrochemical forces acting between the particles and the water, which in turn are influenced by the chemical composition of water. The silt load can be reduced by retention reservoirs or chemical flocculants. Doses of alum in the range 100-150 mg/l, may reduce the suspended matter to 300 mg/l in a few hours, a few polymer compounds can achieve the same effect with doses of 0.3-1.5 mg/l.

Suspended matter clogs the soil in two different ways, firstly the surface of the interstices of the soil may be filled up and a layer or mud may be deposited on the surface. Secondly the suspended particles may penetrate deeper into the soil and accumulate there inhibiting the infiltration. Clogging effects by suspended particles may be minimized by:

a. Periodical removing of mud cake and scrapping of the surface layer

- b. Installation of a filter on the surface, the permeability of which is lower than the natural strata
- c. Addition of chemicals to the uppermost layer
- d. Cultivation of certain plant covers, certain kinds of grass

Clogging by biological activity depends upon the mineralogy and organic composition of the water and basin floor and permeability of floor. This type of clogging can be treated by thoroughly drying the ground under the basin.

4.3.4 Environmental Problems of Artificial Recharging

Artificial recharging projects have to be carried out in the vicinity of densely populated and industrial areas where large quantities of water are needed and may lead to problems such as:

- 1. Stagnant water serves as a breeding ground for mosquitoes, flies and a variety of other biological nuisances. These installations may become an eye sore unless properly tended or an accident hazard due to trespassing by children and is a target of for vandalism.
- 2. Pressures due to the high value of lands in urban centers may prevent the execution of projects. Spreading grounds may appear to be wasteland, which could be better, used for other proposals.
- 3. Artificial recharge is designed to raise water levels, which may cause substantial damage. For example, as a result of heavy

pumping, the water table in a locality may get depressed for many years, as a result basements, underground, and similar structures might have been built below the land surface, there is a distinct possibility that an artificial rise os water table would cause an economic harm.

4. Damage may be caused if the recharged water is of inferior quality. The water imported for recharging may be of treated sewage effluent or of poor chemical quality may also pollute the aquifer whose is of high quality.

Artificial recharge is not a widespread technique and is mainly practiced in industrialized countries. Most of the recharge installations are located in Central, Northern and Western Europe, Israel, Japan and the United State of America.

Developing nations of Africa, Asia and Latin America have less recharging installation because of economic crunch. However, recharging has a great prospect in developing nations because of their rapid industrialization and urbanization. In Maharashtra a number of percolation dams are built and artificial lakes are created to improve groundwater conditions in the areas where a number of wells have sunk.

In India the monsoon is a deluge. Rain spatters the earth. It fills ponds, Lakes and Rivers heave. But the monsoon is also brief. We receive most of its rainfall in just 100 hours out of 8760 hours in a year. But this is enough to meet our water needs, provide food security and eradicate rural poverty. Water Balance in India

According to a study, India receives 400 million hectare meters (mham) of rain and snowfall. Another 20 mham flow in a surface water from outside the country. This total 420 mham provide the country with river flows of 180 mham. Another 67 mham is available as groundwater. About 173 mham is lost as evaporation or becomes soil moisture-which can be captured directly as rainwater or as runoff from small catchments in and near villages or towns. If even 20-3-mham can be captured through rainwater harvesting, tremendous pressure can greatly extend the availability of clean water. Why is Cherrapunji today short of drinking water when it gets more than 11 meters of rainfall annually? Simply because it does not capture the rain that falls over it. i.e. there is no rainwater harvesting. All the water goes down the drain.

The rainwater needs to be harvested through capturing, storing and recharging it and later using it during prolonged parched periods. The sky component of water management is 'storage' especially in India. Any land can be used to harvest rainwater. The most beautiful thing about water harvesting is that there is a human-rain-land synergy. What the table shows clearly is that rainwater harvesting is possible in all human-land-rain scenarios. Kanpur is one of the worst cities in India as far as the environmental conditions are concerned. Water, air, and noise pollution far exceed the permissible levels endangering the health of city dwellers. Kanpur exploits both surface water and groundwater sources. constitute 40% and the surface water

sources 60% of the total supply. The tapping f groundwater is most common in industrial areas and at some places, leaching of disposal effluents has polluted the groundwater.

In Kanpur metro, on the one hand there is the acute water scarcity and on the other, the streets are often flooded during the monsoons. This has led to serious problems with quality and quality of groundwater.

This is despite the fact the Kanpur receives good rainfall. However, this rainfall occurs during short spells of high intensity. Most of the rain falls in just 100 hours out of 8760 hours in a year. Because of such short duration of heavy rain, most of the rain falling on the surface tends to flow away rapidly leaving very little for recharge of groundwater. Most of the traditional water harvesting systems in cities have been neglected and fallen into disuse, worsening the urban water scenario. One of the solutions to the urban water crisis is rainwater harvesting-capturing the runoff.

All the wells and temple tanks in the Kanpur City can be revived. The barrage and percolation dams along the Ganga should be built and artificial lakes can be created in sub-urban low-lying areas to improve ground water conditions particularly in those areas where a number of wells have gone dry and their is lot of contamination. A percolation well of 40 feet deep and 10 feet wide is recommended for new colonies per 1000 m² land area. The rainwater from housetops would collect in the well to supply good

drinking water and recharge groundwater. Artificial recharging projects can be carried out in the vicinity of densely populated and industrial area where large quantities of water are needed but the problems mentioned on section 4.3.04 of the thesis must be taken into consideration. Thus, an interesting new field of research is open for water agencies and international organisations. Rainwater harvesting: is expected to soon become an essential feature in houses built in metro towns of the country. In fact, Delhi has taken the first step an made installation of rainwater harvesting system compulsory for houses built on larger plats of lands.

However, rain harvesting resulting in artificial recharge of groundwater does not offer complete solution to problem of contamination by pollution. The groundwater recharge must be accompanied by the following steps for proper water quality management in urban areas.

4.4.1 Pollution Control at Source/Source Reduction

Many small industries are located in the city and with the rise of industrial growth urban settlements also grow both in size and pollution. Rapid urbanization and industrialization increase the waste water quantity and deteriorates both groundwater and surface water quality. Thus the contamination should be controlled at the initial stage itself. Pollution control at sources may be classified as-

- (a) Waster water reuse: Domestic waster water should be reused for watering lawns and kitchen gardens, thereby helping the waster water disposal in a better way.
- (b) Reduction in pollutants: Programmes should be formulated to encourage reducing the amount of pollutants in products entering the waster stream. Less toxic and problematic substances should be used in products, e.g. substitution for lead and cadmium in ink and paints is such a measure.
- (c) Separate disposal of solid waster: The metro's municipal solid waste increases very year with increase in population. Uncontrolled and unscientific dumping of waste results in accumulation of refuse on streets, public areas, drains, etc., and have serious impacts on soil degradation and water pollution. Solid wastes such as dust, food wastes, packing in the form of paper, metals, worn-out clothing's, construction and demolition wastes, dead bodies of animals, pathological wastes, hazardous wastes, radioactive wastes and dairy products should be disposed separately instead of with water stream. The separated waste finds multiple uses.

4.4.2 Resource Recovery

It involves to recover any resource from the waste, e.g., the organic matter present in the spent wash (in distilleries) is non-sugar in composition and is a rich source of biogas. Wastes have a vast potential for generation power. Industrial wastes are rich in

heavy metals, which can be recovered by various methods, *e.g.*, chrome tanning plant effluent is a measure source of chromium.

4.4.3 Sewerage Regulation

In general practice industrial effluents are discharged into the municipal sewers wherever they exist in a city. A strict code of sewerage regulation is needed so that such discharges do not-

- (i) affect the health of the people working in sewers for its maintenance and operations
- (ii) corrode equipment's in the sewerage and treatment system
- (iii) affect the common treatment process and
- (iv) discharge toxic and persistent pollutants into the municipal sewers.

4.4.4 Role of Private Sector companies

Private sector has to play a vital and deciding role in future in managing water supplies and pollution control. Setting up of larger systems of water supply by partially opening water supplies to private sector such as a joint stock company may be setup to act as investing agent and shares in this water company should be free to trade in market. Decentralization of municipal services and partial exposure to market sources would lead to greater efficiency. The operating and monitoring costs would fall automatically in long term. This would result in job creation and modernization of

hydroelectric plants and ultimately energy saving. Such a project has been a success in Estonia and now has been launched in Romania. Various financial institutions such as World Bank, Asian Development Bank. European Development Bank, etc., should aid in cleaning water for drinking purposes and cities like Kanpur.

It may be stated here that the general discussion about management, conservation of groundwater and technology discussed in the following sections are as relevant to Kanpur (urban and rural) as to any other industrial town of a country a nation.

4.5 Management Of Groundwater Resources

Man's history has been consists of projects to manage surface water resources largely by dams, reservoirs and diversion works. However, managing groundwater is marked principally by lack of real management. Reservoir has been found, it has frequently been deployed without proper planning, and numerous problems have resulted in lowering of water levels in wells and thus increased pumping cost is the most common problem. Poor placement of wells resulting in mutual interference has often been a problem. Depression of water tables and over drought of groundwater reservoirs have frequently occurred resulting in reduction of groundwater supplies or deterioration of its qualities. Therefore, whenever a groundwater resource is fully exploited, it is essential that policy makers be made aware of the limiting

conditions of the use of groundwater storage under varying conditions.

Water management² can be defined as the comprehensive planning for total water resources. With the interdependence of surface and groundwater, any plan for the management of ground water resources be coordinated with plans for management of surface water resources. This would lead to an integrated utilization of water resources making optimal use of the storage potential available above ground and underground.

The main components of water management are as follows:

4.5.1 Demands for Water

Water is one of the most precious gifts of nature. Life and civilizations cannot exist without water. It is vital for production of food and fibre, energy production, improvement of health, industrial development, and so on. White³ has reported a strong correlation between the daily consumption of water and the extent of its availability with readiness and convenience.

The daily minimum requirement of water for prevention of diseases has been estimated to be between 30 to 100 litres/person/day. Water consumption of animals varies the amount varies from with the weight, health, level of activity and climate. Consumption decides the amount to be extracted from groundwater.

Indeed in most cases, all the demands for water cannot be met, and therefore, an acceptable scheme for prioritizing the demands has to redevelop, as the amount of water is limited. This can be met within political, sociological, environmental, ecological and economic framework. In continents with burgeoning population such as Asia, Africa, South America, the importance of water management now is greater than ever before.

4.5.2 Availability of Water

There are three sources of water; atmosphere, hydrosphere and lithosphere. These three sources constitute the global water cycle. The hydrosphere is the major source of water, the atmosphere is the deliverer of water and the lithosphere is the user of water. These three spheres are sometimes clubbed as geosphere. The biosphere continuously interacts with the geosphere through the flow of energy and biogeochemical cycles. Involved in this interaction are both the living and the non-living components. In the water cycle, neither the water is lost nor it is gained, but the amount of water available to the user may fluctuate because of variations at the source or in the delivery system.

4.5.3 External Constraints

Initially the main focus in water management was on satisfaction of water demands and economic efficiency. Now-a-days

scientists and engineers plan and design a scheme based on its physical soundness; economists assess its profitability, social scientists determine its acceptability by public, but it is the politicians who decide its implementation. Once completed, the managers in corporation with public operate and manage it. So water management is to be accomplished not only within the framework of economic efficiency and engineering soundness but is also subject to social, political, environmental, ecological, cultural, institutional and legal constraints. These constraints make water management many fold more complex. Thus, how well the objectives of water management are achieved depends upon the constraints to be satisfied.

4.5.4 Technology of Water Management

The objectives of water management are accomplished by using the tools of system analysis such as **optimizing** (programming) models which attempt to derive the optimal water management scheme for a given objective or set of objectives, and descriptive (predictive) models which attempts to predict the consequences of a management scheme for a known quantity of water. In general following steps are involved in developing a water management scheme:

- (1) Specification of demands for water
- (2) Evaluation of the availability of water
- (3) Specification of constraints
- (4) Statement of objectives and their expression into quantitative criteria
- (5) Selection of an appropriate model
- (6) Derivation of alternative management schemes
- (7) Evaluation of each scheme
- (8) Comparative evaluation of schemes in measurable terms
- (9) Selection of optimal water management scheme

4.6 Water Conservation

Conservation is the preservation and protection of natural environment from destructive influences, misuse, etc. It is most efficient and most beneficial utilization of natural resources and is mainly concerned with the management of the natural resources of the earth, taking into consideration their proper use. As affordable options to augment dependable water supplies demise, the key to feeding the world's growing population, sustaining economic progress and improving living standards lies in learning to use existing supplies more efficiently. Using less water to grow grain, make steel and flush toilet increases the amount of available water

for other uses. The challenge can be met by combining the technologies, economic policies, laws and institution that work best for water conservation or management. The major thrust for conserving water should be in-

4.6.1 Agriculture

It claims the bulk of most nation's water budgets and is by far the largest consumer, saving even a small fraction of this water frees a large amount to meet other needs. Raising irrigation efficiencies worldwide by just 10 per cent would save enough water to supply all global residential water uses. Vast quantities of water seep through unlined canals while in transit to the field and much water is applied to crops than is necessary for them to grow.

Most farmers in developing as well as industrial countries use gravity flow systems to irrigate their fields. Only a small portion of the water reaches the crop's root zone and a large share runs off the field. This system should be replaced by drip or trickle irrigation systems, developed in Isreal in the sixties, supplies water and fertilizer directly onto or below the soil. An extensive network of perforated piping release water close to the plants roots minimizing the evaporation and seepage losses.

Farmers can also reduce water withdrawals by scheduling their irrigation according to actual weather conditions, evapotranspiration rates, soil moisture and their crops' water requirements. Careful scheduling can cut water needs by 20-30 per cent. Irrigation management techniques should be demonstrated to

farmers through mobile laboratories and recommend farmers the ways to use their water efficiently.

4.6.2 Industries

Industries are the second major water drawer of water supplies. In many industries much of the water is used for cooling and other purposes that does not require to be of drinking water quality. Thus, water can be reused several times before disposing it. Thermal power plant like Panki can cut their requirements by 90 per cent or more by using recycled water in cooling towers.

Metal, chemical, food, pulp and paper and petroleum manufacturing industries use a great deal of water and the cost of water is rarely more than 3 per cent of the total expenses. Use of water more efficiently can come from strict water allocations or stringent pollution control equipment's. Developing countries are rapidly moving towards industrialization. These countries can take advantage of new recycling technologies and can reduce water use and waste water flows, and thus can contribute greatly to alleviating water supply and pollution problems in growing urban areas.

4.6.3 Domestic Use

Household and other municipal water demands rarely account for more than 15 per cent of a nation's water budget and worldwide they claim about 7 per cent of total withdrawals. Most household fixtures and appliances use much more water than

necessary to perform their varies functions. The water used in flushing toilets can be reduced greatly by installing toilets of more water efficient designs. Water efficient dishwashers and washing machines can reduce water use 25 to 30 per cent over conventional models. With simple conservation measures, indoor water use can easily be reduced by a third. Installation of various water efficient appliances in homes, apartments and offices may be forced through laws. Fresh water demands can be reduced by using brackish water and wastewater to meet many of the water needs such as irrigation. Treated wastewater can be reused to irrigate crops and gardens, to recharge aquifers and as supply for industries⁵⁻⁶.

4.7 Conclusion

It can be concluded from the above discussion that at the micro level a key to the successful water quality and resource management lies in the combined efforts of social, political, environmental, ecological, cultural, institutional and legal sectors of the society. Better technologies in pollution control, waste control, water supplies, efficient water usage designs, etc., all augment in successful water management. Conservation of water in agriculture, industry and households could break the ice.

However, at the micro-level, the following suggestions will go a long way in reducing groundwater pollution in the times to come groundwater quality in Kanpur .

- a. With regard to observation of excessively high concentration of chromium in study zones of JJ and IA a detailed inventory of possible sources of contamination is being carried out to arrive at specific measures to be adopted.
- b. Strict regulation for safe disposal of diverse type of hazardous waste generated by industries manufacturing basic chrome sulphate (BCS) an important input for the tanneries. At present, there are eight such identified industries situated in and around Kanpur which not only supply BCS to the local tanneries but also connivingly dispose-off their toxic sludge in different parts of Kanpur. It has also been observed that the discarded sublimed sludge rich in chromium has increasingly been stored in Rakhimandi and blended with coal ash which is subsequently used as a building material.
- c. Identification and development of hazardous waste disposal site need to be given due priority and till such time the disposal site is identified and developed, BCS manufacturing units may be asked to store the ash safely in leak proof bags, in properly lined pucca storage tanks to ensure that it is not exposed to sky.
- d. All the slum areas of Kanpur particularly in Jajmau, Panki and on the suburbs be provided with a good sanitation facility.
- e. Indiscriminate roadside disposal of municipal sold waste in Kanpur be critically interpreted in terms of its

- environmental impact, with special emphasis on groundwater contamination.
- f. All the specific locations which exhibit highly contaminated groundwater be immediately declared as unsafe areas by the local authorities and be supplied with alternative measures of drinking water.

REFERENCES

- 1. Wood, W.W. et al., 1977, 'Quantifying macropore recharge: Examples from a semi-arid area', Groundwater,3 (6).
- 2. Natural Resources, 1975, Groundwater Storage and Artificial Recharge, Water Series, No.2 United Nations, New York.
- 3. White, A.U., 'Patterns of domestic water use in low income countries', Water, Wastes and Health in Hot Climates, Ed. R. Feachem, et al., pp.46-112, Wiley, U.K.
- 4. Falkenmark, M., 1989, 'Hydrological phenomena in geosphere-biosphere interactions outlooks to past, present and future', Monographs and Reports No. 1, IAHS, Walling for, U.K.
- 5. **Khan M.A.** et al. 'Development of supplies, and sanitation in Saudi Arabia.
- **6**. Shural HJ., 'The development of waste water reuse in Israel', Proc. of Water reuse symposium.

